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PROTOPLASM AND LIFE.*

By Professor G. J. ALLMAN, LL.D., F.R.S.,
PRESIDENT OF THE BRITISH ASSOCIATION.

MORE than forty years have now passed away since the French naturalist, Dujardin, drew attention to the fact that the bodies of some of the lowest members of the animal kingdom consist of a structureless, semi-fluid, contractile substance, to which he gave the name of Sarcode. A similar substance occurring in the cells of plants was afterward studied by Hugo von Mohl, and named by him Protoplasm. It remained for Max Schultze to demonstrate that the sarcode of animals and the protoplasm of plants were identical.

The conclusions of Max Schultze have been in all respects confirmed by subsequent research, and it has further been rendered certain that this same protoplasm lies at the base of all the phenomena of life, whether in the animal or the vegetable kingdom. Thus has arisen the most important and significant generalization in the whole domain of biological science.

Within the last few years protoplasm has again been made a subject of special study; unexpected and often startling facts have been brought to light, and a voluminous literature has gathered round this new center of research. I believe, therefore, that I can not do better than call your attention to some of the more important results of these inquiries, and endeavor to give you some knowledge of the properties of protoplasm, and of the part it plays in the two great kingdoms of organic nature.

As has just been said, protoplasm lies at the base of every vital phenomenon. It is, as Huxley has well expressed it, "the physical basis of life." Wherever there is life, from its lowest to its highest

* Inaugural Address at the Sheffield meeting, August 20, 1879.

manifestations, there is protoplasm; wherever there is protoplasm, there, too, is life. Thus, coextensive with the whole of organic nature —every vital act being referable to some mode or property of protoplasm—it becomes to the biologist what the ether is to the physicist; only that instead of being an hypothetical conception, accepted as a reality from its adequacy in the explanation of phenomena, it is a tangible and visible reality, which the chemist may analyze in his laboratory, the biologist scrutinize beneath his microscope and his dissecting needle.

The chemical composition of protoplasm is very complex, and has not been exactly determined. It may, however, be stated that protoplasm is essentially a combination of albuminoid bodies, and that its principal elements are, therefore, oxygen, carbon, hydrogen, and nitrogen. In its typical state it presents the condition of a semi-fluid substance—a tenacious, glairy liquid, with a consistence somewhat like that of the white of an unboiled egg.* While we watch it beneath the microscope, movements are set up in it: waves traverse its surface, or it may be seen to flow away in streams, either broad and attaining but a slight distance from the main mass, or else stretching away far from their source, as narrow liquid threads, which may continue simple, or may divide into branches, each following its own independent course; or the streams may flow one into the other, as streamlets would flow into rivulets and rivulets into rivers, and this not only where gravity would carry them, but in a direction diametrically opposed to gravitation: now we see it spreading itself out on all sides into a thin liquid stratum, and again drawing itself together within the narrow limits which had at first confined it, and all this without any obvious impulse from without which would send the ripples over its surface or set the streams flowing from its margin. Though it is certain that all these phenomena are in response to some stimulus exerted on it by the outer world, they are such as we never meet with in a simply physical fluid—they are spontaneous movements resulting from its proper irritability, from its essential constitution as living matter.

Examine it closer, bring to bear on it the highest powers of your microscope—you will probably find disseminated through it countless multitudes of exceedingly minute granules; but you may also find it absolutely homogeneous, and, whether containing granules or not, it is certain that you will find nothing to which the term *organization*

* In speaking of protoplasm as a liquid, it must be borne in mind that this expression refers only to its physical consistence—a condition depending mainly on the amount of water with which it is combined, and subject to considerable variation, from the solid form in which we find it in the dormant embryo of seeds, to the thin, watery state in which it occurs in the leaves of Valisneria. Its distinguishing properties are totally different from those of a purely physical liquid, and are subject to an entirely different set of laws.

can be applied. You have before you a glairy, tenacious fluid, which, if not absolutely homogeneous, is yet totally destitute of structure.

And yet no one who contemplates this spontaneously moving matter can deny that it is alive. Liquid as it is, it is a living liquid; organless and structureless as it is, it manifests the essential phenomena of life.

The picture which I have thus endeavored to trace for you in a few leading outlines is that of protoplasm in its most generalized aspect. Such generalizations, however, are in themselves unable to satisfy the conditions demanded by an exact scientific inquiry, and I propose now, before passing to the further consideration of the place and purport of protoplasm in nature, to bring before you some definite examples of protoplasm, such as are actually met with in the organic world.

A quantity of a peculiar slimy matter was dredged in the North Atlantic by the naturalists of the exploring-ship Porcupine from a depth of from 5,000 to 25,000 feet. It is described as exhibiting, when examined on the spot, spontaneous movements, and as being obviously endowed with life. Specimens of this, preserved in spirits, were examined by Professor Huxley, and declared by him to consist of protoplasm, vast masses of which must thus in a living state extend over wide areas of sea-bottom. To this wonderful slime Huxley gave the name of *Bathybius Haeckelii*.

Bathybius has since been subjected to an exhaustive examination by Professor Haeckel, who believes that he is able to confirm in all points the conclusions of Huxley, and arrives at the conviction that the bottom of the open ocean at depths below 5,000 feet is covered with an enormous mass of living protoplasm, which lingers there in the simplest and most primitive condition, having as yet acquired no definite form. He suggests that it may have originated by spontaneous generation, but leaves this question for future investigations to decide.

The reality of Bathybius, however, has not been universally accepted. In the more recent investigations of the Challenger the explorers have failed in their attempts to bring further evidence of the existence of masses of amorphous protoplasm spreading over the bed of the ocean. They have met with no trace of Bathybius in any of the regions explored by them, and they believe that they are justified in the conclusion that the matter found in the dredgings of the Porcupine and preserved in spirits for further examination, was only an inorganic precipitate due to the action of the alcohol.

It is not easy to believe, however, that the very elaborate investigations of Huxley and Haeckel can be thus disposed of. These, moreover, have received strong confirmation from the still more recent observations of the Arctic voyager Bessels, who was one of the explorers of the ill-fated Polaris, and who states that he dredged from the Greenland seas masses of living undifferentiated protoplasm.

Bessels assigns to these the name of Protobathybius, but they are apparently indistinguishable from the Bathybius of the Porcupine. Further arguments against the reality of Bathybius will therefore be needed before a doctrine founded on observations so carefully conducted shall be relegated to the region of confuted hypotheses.

Assuming, then, that Bathybius, however much its supposed wide distribution may have been limited by more recent researches, has a real existence, it presents us with a condition of living matter the most rudimental it is possible to conceive. No law of morphology has as yet exerted itself in this formless slime. Even the simplest individualization is absent. We have a living mass, but we know not where to draw its boundary-lines; it is living matter, but we can scarcely call it a living being.

We are not, however, confined to Bathybius for examples of protoplasm in a condition of extreme simplicity. Haeckel has found, inhabiting the fresh waters in the neighborhood of Jena, minute lumps of protoplasm which, when placed under the microscope, were seen to have no constant shape, their outline being in a state of perpetual change, caused by the protrusion from various parts of their surface of broad lobes and thick, finger-like projections, which, after remaining visible for a time, would be withdrawn, to make their appearance again on some other part of the surface.

These changeable protrusions of its substance, without fixed position or definite form, are eminently characteristic of protoplasm in some of its simplest conditions. They have been termed "Pseudopodia," and will frequently come before you in what I have yet to say.

To the little protoplasmic lumps thus constituted Haeckel has given the name of *Protamœba primitiva*. They may be compared to minute detached pieces of Bathybius. He has seen them multiplying themselves by spontaneous division into two pieces, which, on becoming independent, increase in size, and acquire all the characters of the parent.

Several other beings as simple as *Protamœba* have been described by various observers, and especially by Haeckel, who brings the whole together into a group to which he gives the name of MONERA, suggested by the extreme simplicity of the beings included in it.

But we must now pass to a stage a little higher in the development of protoplasmic beings. Widely distributed in the fresh and salt waters of Britain, and probably of almost all parts of the world, are small particles of protoplasm closely resembling the *Protamœba* just described. Like it, they have no definite shape, and are perpetually changing their form, throwing out and drawing in thick lobes and finger-like pseudopodia, in which their body seems to flow away over the field of the microscope. They are no longer, however, the homogeneous particle of protoplasm which forms the body of *Protamœba*. Toward the center a small globular mass of firmer protoplasm has

become differentiated off from the remainder, and forms what is known as a nucleus, while the protoplasm forming the extreme outer boundary differs slightly from the rest, being more transparent, destitute of granules, and apparently somewhat firmer than the interior. We may also notice that at one spot a clear spherical space has made its appearance, but that while we watch it has suddenly contracted and vanished, and after a few seconds has begun to dilate so as again to come into view, once more to disappear, then again to return, and all this in regular rhythmical sequence. This little rhythmically pulsating cavity is called the "contractile vacuole." It is of very frequent occurrence among those beings which lie low down in the scale of life.

We have now before us a being which has arrested the attention of naturalists almost from the commencement of microscopical observation. It is the famous *Amœba*, for which ponds and pools and gutters on the house-roof have for the last two hundred years been ransacked by the microscopist, who has many a time stood in amazement at the undefinable form and Protean changes of this particle of living matter. It is only the science of our own days, however, which has revealed its biological importance, and shown that in this little soft, nucleated particle we have a body whose significance for the morphology and physiology of living beings can not be over-estimated, for in *Amœba* we have the essential characters of a CELL, the morphological unit of organization, the physiological source of specialized function.

The term "cell" has been so long in use that it can not now be displaced from our terminology; and yet it tends to convey an incorrect notion, suggesting as it does the idea of a hollow body or vesicle, this having been the form under which it was first studied. The cell, however, is essentially a definite mass of protoplasm having a nucleus imbedded in it. It may or may not assume the form of a vesicle; it may or may not be protected by an enveloping membrane; it may or may not contain a contractile vacuole; and the nucleus may or may not contain within it one or more minute secondary nuclei or "nucleoli."

Haeckel has done good service to biology in insisting on the necessity of distinguishing such non-nucleated forms as are presented by *Protamœba* and the other *Monera* from the nucleated forms as seen in *Amœba*. To the latter he would restrict the word *cell*, while he would assign that of "cytode" to the former.

Let us observe our *Amœba* a little closer. Like all living beings, it must be nourished. It can not grow as a crystal would grow by accumulating on its surface molecule after molecule of matter. It must *feed*. It must take into its substance the necessary nutriment; it must assimilate this nutriment, and convert it into the material of which it is itself composed.

If we seek, however, for a mouth by which the nutriment can enter into its body, or a stomach by which this nutriment can be digest-

ed, we seek in vain. Yet watch it for a moment as it lies in a drop of water beneath our microscope. Some living denizen of the same drop is in its neighborhood, and its presence exerts on the protoplasm of the *Amœba* a special stimulus which gives rise to the movements necessary for the prehension of nutriment. A stream of protoplasm instantly runs away from the body of the *Amœba* toward the destined prey, envelops it in its current, and then flows back with it to the central protoplasm, where it sinks deeper and deeper into the soft, yielding mass, and becomes dissolved, digested, and assimilated in order that it may increase the size and restore the energy of its captor.

But again, like all living things, *Amœba* must multiply itself, and so after attaining a certain size its nucleus divides into two halves, and then the surrounding protoplasm becomes similarly cleft, each half retaining one half of the original nucleus. The two new nucleated masses which thus arise now lead an independent life, assimilate nutriment, and attain the size and characters of the parent.

We have just seen that in the body of an *Amœba* we have the type of a cell. Now, both the fresh waters and the sea contain many living beings besides *Amœba* which never pass beyond the condition of a simple cell. Many of these, instead of emitting the broad, lobe-like pseudopodia of *Amœba*, have the faculty of sending out long, thin threads of protoplasm, which they can again retract, and by the aid of which they capture their prey or move from place to place. Simple structureless protoplasm as they are, many of them fashion for themselves an outer membranous or calcareous case, often of symmetrical form and elaborate ornamentation, or construct a silicious skeleton of radiating spicula, or crystal clear concentric spheres of exquisite symmetry and beauty.

Some move about by the aid of a flagellum, or long whip-like projection of their bodies, by which they lash the surrounding waters, and which, unlike the pseudopodia of *Amœba*, can not, during active life, be withdrawn into the general protoplasm of the body; while among many others locomotion is effected by means of cilia—microscopic vibratile hairs, which are distributed in various ways over the surface, and which, like the pseudopodia and flagella, are simple prolongations of their protoplasm.

In every one of these cases the entire body has the morphological value of a cell, and in this simple cell reside the whole of the properties which manifest themselves in the vital phenomena of the organism.

The part fulfilled by these simple unicellular beings in the economy of nature has at all times been very great, and many geological formations, largely built up of their calcareous or silicious skeletons, bear testimony to the multitudes in which they must have swarmed in the waters of the ancient earth.

Those which have thus come down to us from ancient times owe

their preservation to the presence of the hard, persistent structures secreted by their protoplasm, and must, after all, have formed but a very small proportion of the unicellular organisms which peopled the ancient world, and there fulfilled the duties allotted to them in nature, but whose soft, perishable bodies have left no trace behind.

In our own days similar unicellular organisms are at work, taking their part silently and unobtrusively in the great scheme of creation, and mostly destined, like their predecessors, to leave behind them no record of their existence. The Red-Snow plant, to which is mainly due the beautiful phenomenon by which tracts of Arctic and Alpine snow become tinged of a delicate crimson, is a microscopic organism whose whole body consists of a simple spherical cell. In the protoplasm of this little cell must reside all the essential attributes of life; it must grow by the reception of nutriment; it must repeat by multiplication that form which it has itself inherited from its parent; it must be able to respond to the stimulus of the physical conditions by which it is surrounded. And there it is, with its structure almost on the bounds of extremest simplification, taking its allotted part in the economy of nature, combining into living matter the lifeless elements which lie around it, redeeming from sterility the regions of never-thawing ice, and peopling with its countless millions the wastes of the snow-land.*

But organization does not long rest on this low stage of unicellular simplicity, for, as we pass from these lowest forms into higher, we find cell added to cell, until many millions of such units become associated in a single organism, where each cell, or each group of cells, has its own special work, while all combine for the welfare and unity of the whole.

In the most complex animals, however, even in man himself, the component cells, notwithstanding their frequent modification and the usual intimacy of their union, are far from losing their individuality. Examine under the microscope a drop of blood freshly taken from the human subject, or from any of the higher animals. It is seen to be composed of a multitude of red corpuscles, swimming in a nearly colorless liquid, and along with these, but in much smaller numbers, somewhat larger colorless corpuscles. The red corpuscles are modified cells, while the colorless corpuscles are cells still retaining their typical form and properties. These last are little masses of protoplasm, each enveloping a central nucleus. Watch them. They will be seen to change their shape; they will project and withdraw pseudopodia, and creep about like an *Amœba*. But, more than this, like an *Amœba*, they will take in solid matter as nutriment. They may be fed with

* The Red-Snow plant (*Protococcus nivalis*) acts on the atmosphere through the agency of chlorophyl, like the ordinary green plants. As in these, chlorophyl is developed in it, and is only withdrawn from view by the predominant red pigment to which the Protococcus owes one of its most striking characteristics.

colored food, which will then be seen to have accumulated in the interior of their soft, transparent protoplasm; and in some cases the colorless blood-corpuscles have actually been seen to devour their more diminutive companions, the red ones.

Again, there are certain cells filled with peculiar colored matters, and called pigment-cells, which are especially abundant, as constituents of the skin, in fishes, frogs, and other low vertebrate, as well as many invertebrate, animals. Under certain stimuli, such as that of light, or of emotion, these pigment-cells change their form, protrude or retract pseudopodial prolongations of their protoplasm, and assume the form of stars or of irregularly lobed figures, or again draw themselves together into little globular masses. To this change of form in the pigment-cell the rapid change of color, so frequently noticed in the animals provided with them, is to be attributed.

The animal egg, which in its young state forms an element in the structure of the parent organism, possesses in the relations now under consideration a peculiar interest. The egg is a true cell, consisting essentially of a lump of protoplasm inclosing a nucleus, and having a nucleolus included in the interior of the nucleus. While still very young it has no constant form, and is perpetually changing its shape. Indeed, it is often impossible to distinguish it from the *Amœba;* and it may, like an *Amœba*, wander from place to place by the aid of its pseudopodial projections. I have shown elsewhere * that the primitive egg of the remarkable hydroid *Myriothela* manifests amœboid motions; while Haeckel has shown † that in the sponges certain *Amœba*-like organisms, which are seen wandering about in the various canals and cavities of their bodies, and had been until lately regarded as parasites which had gained access from without, are really the eggs of the sponge; and a similar amœboid condition is presented by the very young eggs of even the highest animals.

Again, Reichenbach has proved ‡ that during the development of the crawfish the cells of the embryo throw out pseudopodia by which, exactly as in an *Amœba*, the yolk-spheres, which serve as nutriment for the embryo, are surrounded and ingulfed in the protoplasm of the cells.

I had shown some years ago § that in *Myriothela* pseudopodial processes are being constantly projected from the walls of the alimentary canal into its cavity. They appear as direct extensions of a layer of clear, soft, homogeneous protoplasm, which lies over the surface of the naked cells lining the cavity, and which I now regard as the

* "On the Structure and Development of *Myriothela*," "Philosophical Transactions," vol. clxv., 1875, p. 552.

† "Jenaische Zeitschrift," 1871.

‡ "Die Embryonanlage und erste Entwickelung des Flusskrebse," "Zeitschrift für wissenschaftliche Zoologie," 1877.

§ *Loc. cit.*

"Hautschicht," or cortical layer, of these cells. I then suggested that the function of these pseudopodia lay in seizing, in the manner of an *Amœba*, such alimentary matter as may be found in the contents of the canal, and applying it to the nutrition of the hydroid.

What I had thus suggested with regard to *Myriothela* has been since proved in certain planarian worms by Metschnikoff,* who has seen the cells which line the alimentary canal in these animals act like independent *Amœbæ*, and ingulf in their protoplasm such solid nutriment as may be contained in the canal. When the planaria was fed with coloring matter these amœboid cells became gorged with the colored particles just as would have happened in an *Amœba* when similarly fed.

But it is not alone in such loosely aggregated cells as those of the blood, or in the amœboid cells of the alimentary canal, or in such scattered constituents of the tissues as the pigment-cells, or in cells destined for an ultimate state of freedom, as the egg, that there exists an independence. The whole complex organism is a society of cells, in which every individual cell possesses an independence, an autonomy, not at once so obvious as in the blood-cells, but not the least real. With this autonomy of each element there is at the same time a subordination of each to the whole, thus establishing a unity in the entire organism, and a concert and harmony between all the phenomena of its life.

In this society of cells each has its own work to perform, and the life of the organism is made up of the lives of its component cells. Here it is that we find most distinctly expressed the great law of the physiological division of labor. In the lowest organisms, where the whole being consists of a single cell, the performance of all the processes which constitute its life must devolve on the protoplasm of this one cell; but as we pass to more highly organized beings, the work becomes distributed among a multitude of workers. These workers are the cells which now make up the complex organism. The distribution of labor, however, is not a uniform one, and we are not to suppose that the work performed by each cell is but a repetition of that of every other. For the life-processes, which are accumulated in the single cell of the unicellular organism become in the more complex organism differentiated, some being intensified and otherwise modified and allocated to special cells, or to special groups of cells, which we call organs, and whose proper duty is now to take charge of the special processes which have been assigned to them. In all this we have a true division of labor—a division of labor, however, by no means absolute; for the processes which are essential to the life of the cell must still continue common to all the cells of the organism. No cell, however great may be the differentiation of function in the organism,

* "Ueber die Verdauungsorgane einiger Süsswasser-Turbellarien," "Zoologischer Anzeiger," December, 1878.

can dispense with its irritability, the one constant and essential property of every living cell. There thus devolves on each cell or group of cells some special work which contributes to the well-being of all, and their combined labors secure the necessary conditions of life for every cell in the community, and result in those complex and wonderful phenomena which constitute the life of the higher organisms.

We have hitherto considered the cell only as a mass of active nucleated protoplasm, either absolutely naked, or partially inclosed in a protective case, which still permits free contact of the protoplasm with the surrounding medium. In very many instances, however, the protoplasm becomes confined within resisting walls, which entirely shut it in from all direct contact with the medium which surrounds it. With the plant this is almost always so after the earliest stages of its life. Here the protoplasm of the cells is endowed with the faculty of secreting over its surface a firm, resisting membrane, composed of cellulose, a substance destitute of nitrogen, thus totally different from the contained protoplasm, and incapable of manifesting any of the phenomena of life.

Within the walls of cellulose the protoplasm is now closely imprisoned, but we are not on that account to suppose that it has lost its activity, or has abandoned its work as a living being. Though it is now no longer in direct contact with the surrounding medium, it is not the less dependent on it, and the reaction between the imprisoned protoplasm and the outer world is still permitted by the permeability of the surrounding wall of cellulose.

When the protoplasm thus becomes surrounded by a cellulose wall it seldom retains the uniform arrangement of its parts which is often found in the naked cells. Minute cavities or vacuoles make their appearance in it; these increase in size and run one into the other, and may finally form one large cavity in the center, which becomes filled with a watery fluid, known as the cell-sap. This condition of the cell was the first observed, and it was it which suggested the often inapplicable term "cell." By the formation of this central sap cavity the surrounding protoplasm is pushed aside, and pressed against the cellulose wall, over which it now extends as a continuous layer. The nucleus either continues near the center, enveloped by a layer of protoplasm, which is connected by radiating bands of protoplasm with that of the walls, or it accompanies the displaced protoplasm, and lies imbedded in this on the walls of the cell.

We have abundant evidence to show that the imprisoned protoplasm loses none of its activity. The *Characæ* constitute an exceedingly interesting group of simple plants, common in the clear water of ponds and of slowly running streams. The cells of which they are built up are comparatively large, and, like almost all vegetable cells, are each inclosed in a wall of cellulose. The cellulose is perfectly transparent, and if the microscope, even with a low power, be brought

to bear on one of these cells, a portion of its protoplasm may be seen in active rotation, flowing up one side of the long, tubular cell and down the other, and sweeping on with it such more solid particles as may become enveloped in its current. In another water-plant, the *Valisneria spiralis*, a similar active rotation of the protoplasm may be seen in the cells of the leaf, where the continuous stream of liquid protoplasm sweeping along the green granules of chlorophyl, and even carrying the globular nucleus with it in its current, presents one of the most beautiful of the many beautiful phenomena which the microscope has revealed to us.

In many other cells with large sap-cavities, such as those which form the stinging hairs of nettles and other kinds of vegetable hairs, the protoplasmic lining of the wall may send off into the sap-cavity projecting ridges and strings, forming an irregular network, along which, under a high power of the microscope, a slow streaming of granules may be witnessed. The form and position of this protoplasmic network undergo constant changes, and the analogy with the changes of form in an *Amœba* becomes obvious. The external wall of cellulose renders it impossible for the confined protoplasm to emit, like a naked *Amœba*, pseudopodia from its outer side; but on the inner side there is no obstacle to the extension of the protoplasm, and here the cavity of the cell becomes more or less completely traversed by protoplasmic projections from the wall. These often stretch themselves out in the form of thin filaments, which, meeting with a neighboring one, become fused into it; they show currents of granules streaming along their length, and after a time become withdrawn and disappear. The vegetable cell, in short, with its surrounding wall of cellulose, is in all essential points a closely imprisoned rhizopod.

Further proof that the imprisoned protoplasm has lost by its imprisonment none of its essential irritability, is afforded by the fact that if the transparent cell of a Nitella, one of the simple water-plants just referred to, be touched under the microscope with the point of a blunt needle, its green protoplasm will be seen to recede, under the irritation of the needle, from the cellulose wall. If the cellulose wall of the comparatively large cell which forms the entire plant in a Vaucheria, a unicellular alga very common in shallow ditches, be ruptured under the microscope, its protoplasm will escape, and may then be often seen to throw out pseudopodial projections and exhibit amœboid movements.

Even in the higher plants, without adducing such obvious and well-known instances as those of the sensitive-plant and Venus's flytrap, the irritability of the protoplasm may be easily rendered manifest. There are many herbaceous plants, in which, if the young, succulent stem of a vigorously growing specimen receive a sharp blow, of such a nature, however, as not to bruise its tissues, or in any way wound it, the blow will sometimes be immediately followed by a drooping of the

stem commencing at some distance above the point to which the stroke had been applied; its strength appears to have here suddenly left it; it is no longer able to bear its own weight, and seems to be dying. The protoplasm, however, of its cells, is in this instance not killed, it is only stunned by the violence of the blow, and needs time for its restoration. After remaining, it may be for some hours, in this drooping and flaccid state, the stem begins to raise itself, and soon regains its original vigor. This experiment will generally succeed well in plants with a rather large terminal spike or raceme, when the stroke is applied some little distance below the inflorescence shortly before the expansion of the flower.

In the several instances now adduced, the protoplasm is in the mature state of the plant entirely included within a wall of cellulose. Some recent beautiful observations, however, of Mr. Francis Darwin have shown that even in the higher plants truly naked protoplasm may occur. From the cells of certain glandular hairs contained within the cup-like receptacles formed by the united bases of two opposite leaves in the teasel (*Dipsacus*), he has seen emitted long, pseudopodia-like projections of the protoplasm. What may be the significance of this very exceptional phenomenon is still undetermined. It is probably, as Mr. Darwin supposes, connected with the absorption of nitrogenous matter.

That there is no essential difference between the protoplasm of plants and that of animals is rendered further evident by other motor phenomena, which we are in the habit of regarding as the exclusive attribute of animals. Many of the more simply organized plants give origin to peculiar cells called spores, which separate from the parent, and, like the seeds of the higher plants, are destined to repeat its form. In many cases these spores are eminently locomotive. They are then termed "swarm-spores," and their movements are brought about, sometimes by changes of shape, when they move about in the manner of an *Amœba*, but more frequently by minute vibratile cilia, or by more strongly developed flagella or whip-like projections of their protoplasm. These cilia and flagella are absolutely indistinguishable from similar structures widely distributed among animals, and by their vibratory or lashing strokes upon the surrounding water the swarm-spores are rapidly carried from place to place. In these motions they often present a curious semblance of volition, for if the swarm-spore meet with an obstacle in its course, it will, as if to avoid it, change the direction of its motion, and retreat by a reversion of the stroke of its cilia. They are usually attracted by light, and congregate at the light side of the vessel which contains them, though in some cases light has the opposite effect on them, and they recede from it.

Another fact may here be adduced to show the uniform character of protoplasm, and how very different are its properties from those of lifeless matter, namely, the faculty which all living protoplasm possesses

of resisting the entrance of coloring matter into its substance. As many here present are aware, microscopists are in the habit of using in their investigations various coloring matters, such as solutions of carmine. These act differently on the different tissues, staining some, for example, more deeply than others, and thus enabling the histologist to detect certain elements of structure, which would otherwise remain unknown. Now, if a solution of carmine be brought into contact with living protoplasm, this will remain, so long as it continues alive, unaffected by the coloring matter. But if the protoplasm be killed, the carmine will at once pervade its whole substance, and stain it throughout with a color more intense than even that of the coloring solution itself.

But no more illustrative example can be offered of the properties of protoplasm as living matter, independently of any part it may take in organization, than that presented by the *Myxomycetæ*.

The *Myxomycetæ* constitute a group of remarkable organisms, which, from their comparatively large size and their consisting, during a great part of their lives, of naked protoplasm, have afforded a fine field for research, and have become one of the chief sources from which our knowledge of the nature and phenomena of protoplasm has been derived.

They have generally been associated by botanists with the fungi, but though their affinities with these are perhaps closer than with any other plants, they differ from them in so many points, especially in their development, as to render this association untenable. They are found in moist situations, growing on old tan or on moss, or decaying leaves or rotten wood, over which they spread in the form of a network of naked protoplasmic filaments, of a soft, creamy consistence, and usually of a yellowish color.

Under the microscope the filaments of the network exhibit active spontaneous movements, which, in the larger branches, are visible under an ordinary lens, or even by the naked eye. A succession of undulations may then be noticed passing along the course of the threads. Under higher magnifying powers a constant movement of granules may be seen flowing along the threads, and streaming from branch to branch of this wonderful network. Here and there offshoots of the protoplasm are projected, and again withdrawn in the manner of the pseudopodia of an *Amœba*, while the whole organism may be occasionally seen to abandon the support over which it had grown, and to creep over neighboring surfaces, thus far resembling in all respects a colossal ramified *Amœba*. It is also curiously sensitive to light, and may be sometimes found to have retreated during the day to the dark side of the leaves, or into the recesses of the tan over which it had been growing, and again to creep out on the approach of night.

After a time there arise from the surface of this protoplasmic net oval capsules or spore-cases, in which are contained the spores or repro-

ductive bodies of the *Myxomycetæ*. When the spore-case has arrived at maturity, it bursts and allows the spores to escape. These are in the form of spherical cells, each included in a delicate membranous wall, and when they fall into water the wall becomes ruptured, and the little cell creeps out. This consists of a little mass of protoplasm with a round central nucleus, inclosing a nucleolus, and with a clear vacuole, which exhibits a rhythmically pulsating movement. The little naked spore thus set at liberty is soon seen to be drawn out at one point into a long, vibratile, whip-like flagellum, which by its lashing action carries the spore from place to place. After a time the flagellum disappears, and the spore may now be seen emitting and withdrawing finger-like pseudopodia, by means of which it creeps about like an *Amœba*, and like an *Amœba* devours solid particles by ingulfing them in its soft protoplasm.

So far these young *Amœba*-like *Myxomycetæ* have enjoyed each an independent existence. Now, however, a singular and significant phenomenon is presented. Two or more of these *Myxamœbæ*, as they have been called, approach one another, come into contact, and finally become completely fused together into a single mass of protoplasm, in which the components are no longer to be distinguished. To the body thus formed by the fusion of the *Myxamœbæ* the name of "plasmodium" has been given.

The plasmodium continues, like the simple amœbiform bodies of which it is composed, to grow by the ingestion and assimilation of solid nutriment, which it envelops in its substance; it throws out ramifying and mosculating processes, and finally becomes converted into a protoplasmic network, which in its turn gives rise to spore-cases with their contained spores, and thus completes the cycle of its development.

Under certain external conditions, the *Myxomycetæ* have been observed to pass from an active mobile state into a resting state, and this may occur both in the amœbiform spores and in the plasmodium. When the plasmodium is about to pass into a resting state, it usually withdraws its finer branches, and expels such solid ingesta as may be included in it. Its motions then gradually cease, it breaks up into a multitude of polyhedral cells, which, however, remain connected, and the whole body dries into a horny brittle mass, known by the name of "sclerotium."

In this condition, without giving the slightest sign of life, the sclerotium may remain for many months. Life, however, is not destroyed; its manifestations are only suspended; and if after an indefinite time the apparently dead sclerotium be placed in water, it immediately begins to swell up, the membranous covering of its component cells becomes dissolved and disappears, and the cells themselves flow together into an active amœboid plasmodium.

We have already seen that every cell possesses an autonomy or in-

dependent individuality, and from this we should expect that, like all living beings, it had the faculty of multiplying itself, and of becoming the parent of other cells. This is truly the case, and the process of cell-multiplication has of late years been studied, with the result of adding largely to our knowledge of the phenomena of life.

The labors of Strasburger, of Auerbach, of Oscar Hertwig, of Eduard van Beneden, Bütschli, Fol, and others, here come prominently before us, but neither the time at my disposal nor the purport of this address will allow me to do more than call your attention to some of the more striking results of their investigations.

By far the most frequent mode of multiplication among cells shows itself in a spontaneous division of the protoplasm into two separate portions, which then become independent of one another, so that instead of the single parent cell two new ones have made their appearance. In this process the nucleus usually takes an important part. Strasburger has studied it with great care in certain plant-cells, such as the so-called "corpuscula" or "secondary embryo-sacs" of the Coniferæ and the cells of Spirogyra; and has further shown a close correspondence between cell division in animals and that in plants.

It may be generally stated as the results of his observations on the corpuscula of the *Coniferæ*, that the nucleus of the cell about to divide assumes a spindle-shape, and at the same time presents a peculiar striated differentiation, as if it were composed of parallel filaments reaching from end to end of the spindle. These filaments become thickened in the middle, and there form by the approximation of the thickened portions a transverse plate of protoplasm (the "nucleus-plate"). This soon splits into two halves, which recede from one another toward the poles of the spindle, traveling in this course along the filaments, which remain continuous from end to end. When arrived near the poles they form there two new nuclei, still connected with one another by the intervening portion of the spindle.

In the equator of this intervening portion there is now formed in a similar way a second plate of protoplasm (the "cell-plate"), which, extending to the walls of the dividing cell, cuts the whole protoplasm into two halves, each half containing one of the newly-formed nuclei. This partition plate is at first single, but it soon splits into two laminæ, which become the apposed bounding surfaces of the two protoplasm masses into which the mother cell has been divided. A wall of cellulose is then all at once secerted between them, and the two daughter cells are complete.

It sometimes happens in the generation of cells that a young brood of cells arises from the parent cell by what is called "free-cell formation." In this only a part of the protoplasm of the mother cell is used up in the production of the offspring. It is seen chiefly in the formation of the spores of the lower plants, in the first foundation of the embryo in the higher, and in the formation of the endosperm—a

cellular mass which serves as the first nutriment for the embryo—in the seeds of most Phanerogams. The formation of the endosperm has been carefully studied by Strasburger in the embyro-sac of the kidney-bean, and may serve as an example of the process of free-cell formation. The embryo-sac is morphologically a large cell with its protoplasm, nucleus, and cellulose wall, while the endosperm which arises within it is composed of a multitude of minute cells united into a tissue. The formation of the endosperm is preceded by the dissolution and disappearance of the nucleus of the embryo-sac, and then in the midst of the protoplasm of the sac several new nuclei make their appearance. Around each of these as a center the protoplasm of the mother cell is seen to have become differentiated in the form of a clear spherule, and we have thus corresponding to each of the new nuclei a young naked cell, which soon secretes over its surface a membrane of cellulose. The new cells, when once formed, multiply by division, press one on the other, and so combining into a cellular mass, constitute the completed endosperm.

Related to the formation of new cells, whether by division or by free-cell formation, is another very interesting phenomenon of living protoplasm known as "rejuvenescence." In this the whole protoplasm of a cell, by a new arrangement of its parts, assumes a new shape and acquires new properties. It then abandons its cellulose chamber, and enters on a new and independent life in the surrounding medium.

A good example of this is afforded by the formation of swarm-spores in *Œdogonium*, one of the fresh-water algæ. Here the whole of the protoplasm of an adult cell contracts, and by the expulsion of its cell-sap changes from a cylindrical to a globular shape. Then one spot becomes clear, and a pencil of vibratile cilia here shows itself. The cellulose wall which had hitherto confined it now becomes ruptured, and the protoplasmic sphere, endowed with new faculties of development and with powers of active locomotion, escapes as a swarm-spore, which, after enjoying for a time the free life of an animal, comes to rest, and develops itself into a new plant.

The beautiful researches which have within the last few years been made by the observers already mentioned, on the division of animal cells, show how close is the agreement between plants and animals in all the leading phenomena of cell-division, and afford one more proof of the essential unity of the two great organic kingdoms.

There is one form of cell which, in its relation to the organic world, possesses a significance beyond that of every other, namely, the egg. As already stated, the egg is, wherever it occurs, a typical cell, consisting essentially of a globule of protoplasm enveloping a nucleus (the "germinal vesicle"), and with one or more nucleoli (the "germinal spots") in the interior of the nucleus. This cell, distinguishable by no tangible characters from thousands of other cells, is nevertheless destined to run through a definite series of developmental changes,

which have as their end the building up of an organism like that to which the egg owes its origin.

It is obvious that such complex organisms as thus result—composed, it may be, of countless millions of cells—can be derived from the simple egg-cell only by a process of cell-multiplication. The birth of new cells derived from the primary cell or egg thus lies as the basis of embryonic development. It is here that the phenomena of cell-multiplication in the animal kingdom can in general be most satisfactorily observed, and the greater number of recent researches into the nature of these phenomena, have found their most fertile field in the early periods of the development of the egg.

A discussion of the still earlier changes which the egg undergoes in order to bring it into the condition in which cell-multiplication may be possible, would, however full of interest, be here out of place; and I shall therefore confine myself to the first moments of actual development—to what is called "the cleavage of the egg"—which is nothing more than a multiplication of the egg-cell by repeated division. I shall further confine myself to an account of this phenomenon as presented in typical cases, leaving out of consideration certain modifications which would only complicate and obscure our picture.

The egg, notwithstanding the preliminary changes to which I have alluded, is still at the commencement of development a true cell. It has its protoplasm and its nucleus, and it is, as a rule, enveloped in a delicate membrane. The protoplasm forms what is known as the vitellus, or yolk, and the surrounding membrane is called the "vitellary membrane." The division which is now about to take place in it is introduced by a change of form in the nucleus. This becomes elongated, and assumes the shape of a spindle, similar to what we have already seen in the cell-division of plants. On each pole of the spindle transparent protoplasm collects, forming here a clear spherical area.

At this time a very striking and characteristic phenomenon is witnessed in the egg. Each pole of the spindle has become the center of a system of rays which stream out in all directions into the surrounding protoplasm. The protoplasm thus shows, enveloped in its mass, two sun-like figures, whose centers are connected with one another by the spindle-shaped nucleus. To this, with the sun-like rays streaming from its poles, Auerbach gives the name of "Karyolitic figure," suggested by its connection with the breaking up of the original nucleus, to which our attention must next be directed.

A phenomenon similar to one we have already seen in cell-division among plants now shows itself. The nucleus becomes broken up into a number of filaments, which lie together in a bundle, each filament stretching from pole to pole of the spindle. Exactly in its central point every filament shows a knot-like enlargement, and from the close approximation of the knots there results a thick zone of protoplasm in the equator of the spindle. Each knot soon divides into two halves,

and each half recedes from the equator and travels along the filament toward its extremity. When arrived at the poles of the spindle each set of half knots becomes fused together into a globular body, while the intervening portion of the spindle, becoming torn up, and gradually drawn into the substance of the two globular masses, finally disappears. And now, instead of the single fusiform nucleus, whose changes we have been tracing, we have two new globular nuclei, each occupying the place of one of its poles, and formed at its expense.* The egg now begins to divide along a plane at right angles to a line connecting the two nuclei. The division takes place without the formation of a cell-plate such as we saw in the division of the plant-cell, and is introduced by a constriction of its protoplasm, which commences at the circumference just within the vitelline membrane, and extending toward the center, divides the whole mass of protoplasm into two halves, each including within it one of the new nuclei. Thus the simple cell which constituted the condition of the egg at the commencement of development becomes divided into two similar cells. This forms the first stage of cleavage. Each of these two young cells divides in its turn in a direction at right angles to the first division-plane, while by continued repetition of the same act the whole of the protoplasm or yolk becomes broken up into a vast multitude of cells, and the unicellular organism—the egg, with which we began our history—has become converted into an organism composed of many thousands of cells. This is one of the most widely distributed phenomena of the organic world. It is called "the cleavage of the egg," and consists essentially in the production, by division, of successive broods of cells from a single ancestral cell—the egg.

It is no part of my purpose to carry on the phenomena of development further than this. Such of my hearers as may desire to become

* Though none of the above-mentioned observers, to whom we owe our knowledge of the phenomena here described, seem to have thought of connecting the fibrous condition assumed by the spindle with any special structure of the quiescent nucleus, it is highly probable that it consists in a rearrangement of fibers already present. That this is really the case is borne out by the observations of Schleicher on the division of cartilage-cells. ("Die Knorpelzelltheilung," "Arch. für mikr. Anat.," Band xvi., Heft 2, 1878.) From these it would appear that, in the division of cartilage-cells, the investing membrane of the nucleus first becomes torn up, and then the filaments, rodlets, and granules, which, according to him, form its body, enter into a state of intense motor activity, and may be seen arranging themselves into star-like, or wreath-like, or irregular figures, while the whole nucleus, now deprived of its membrane, may wander about the cell, traveling toward one of its poles, and then toward the other; or it may at one time contract, and then again dilate, to such an extent as nearly to fill the entire cell. To this nuclear activity Schleicher applies the term "Karyokinesis." It results in a nearly parallel arrangement of the nuclear filaments. Then these converge at their extremities and become more widely separated in the middle, so as to give to the nucleus the form of a spindle. The filaments then become fused together at each pole of the spindle, so as to form the two new nuclei, which are at first nearly homogeneous, but which afterward become broken up into their component filaments, rods, and granules.

acquainted with the further history of the embryo, I would refer to the excellent address delivered two years ago at the Plymouth meeting of the Association by one of my predecessors in this chair—Professor Allen Thompson.

That protoplasm, however, may present a phenomenon the reverse of that in which a simple cell becomes multiplied into many, is shown by a phenomenon already referred to—the production of plasmodia in the *Myxomycetæ* by the fusion into one another of cells originally distinct.

The genus *Myriothela* will afford another example in which the formation of plasmodia becomes introduced into the cycle of development. The primitive eggs are here, as elsewhere, true cells with nucleolated nuclei, but without any boundary membrane. They are formed in considerable numbers, but remain only for a short time separate and distinct. After this they begin to exhibit amœboid changes of shape, project pseudopodial prolongations which coalesce with those of others in their vicinity, and, finally, a multitude of these primitive ova become fused together into a common plasmodium, in which, as in the simple egg-cell of other animals, the phenomena of development take place.

In many of the lower plants a very similar coalescence is known to take place between the protoplasmic bodies of separate cells, and constitutes the phenomenon of conjugation. *Spirogyra* is a genus of algæ, consisting of long, green threads common in ponds. Every thread is composed of a series of cylindrical chambers of transparent cellulose placed end to end, each containing a sac of protoplasm with a large quantity of cell-sap, and with a green band of chlorophyl wound spirally on its walls. When the threads have attained their full growth they approach one another in pairs, and lie in close proximity, parallel one to the other. A communication is then established by means of short connecting-tubes between the chambers of adjacent filaments, and across the channel thus formed the whole of the protoplasm of one of the conjugating chambers passes into the cavity of the other, and then immediately fuses with the protoplasm it finds there. The single mass thus formed shapes itself into a solid oval body, known as a "zygospore." This now frees itself from the filament, secretes over its naked surface a new wall of cellulose, and, when placed in the conditions necessary for its development, attaches itself by one end, and then, by repeated acts of cell-division, grows into a many-celled filament like those in which it originated.

The formation of plasmodia, regarded as a coalescence and absolute fusion into one another of separate, naked masses of protoplasm, is a phenomenon of great significance. It is highly probable that, notwithstanding the complete loss of individuality in the combining elements, such differences as may have been present in these will always find themselves expressed in the properties of the resulting plas-

modia—a fact of great importance in its bearing on the phenomena of inheritance. Recent researches, indeed, render it almost certain that fertilization, whether in the animal or the vegetable kingdom, consists essentially in the coalescence and consequent loss of individuality of the protoplasmic contents of two cells.

In by far the greater number of plants the protoplasm of most of the cells which are exposed to the sunlight undergoes a curious and important differentiation, part of it becoming separated from the remainder in the form usually of green granules, known as chlorophyl-granules. The chlorophyl-granules thus consist of true protoplasm, their color being due to the presence of a green coloring matter, which may be extracted, leaving behind the colorless protoplasmic base.

The coloring matter of chlorophyl presents under the spectroscope a very characteristic spectrum. For our knowledge of its optical properties, on which time will not now permit me to dwell, we are mainly indebted to the researches of your townsman, Dr. Sorby, who has made these the subject of a series of elaborate investigations, which have contributed largely to the advancement of an important department of physical science.

That the chlorophyl is a living substance, like the uncolored protoplasm of the cell, is sufficiently obvious. When once formed, the chlorophyl-granule may grow by intussusception of nutriment to many times its original size, and may multiply itself by division.

To the presence of chlorophyl is due one of the most striking aspects of external nature—the green color of the vegetation which clothes the surface of the earth: and with its formation is introduced a function of fundamental importance in the economy of plants, for it is on the cells which contain this substance that devolves the faculty of decomposing carbonic acid. On this depends the assimilation of plants, a process which becomes manifest externally by the exhalation of oxygen. Now, it is under the influence of light on the chlorophyl-containing cell that this evolution of oxygen is brought about. The recent observations of Draper and of Pfeffer have shown that in this action the solar spectrum is not equally effective in all its parts; that the yellow and least refrangible rays are those which act with most intensity; that the violent and other highly refrangible rays of the visible spectrum take but a very subordinate part in assimilation; and that the invisible rays which lie beyond the violet are totally inoperative.

In almost every grain of chlorophyl one or more starch-granules may be seen. This starch is chemically isomeric with the cellulose cell-wall, with woody fiber, and other hard parts of plants, and is one of the most important products of assimilation. When plants whose chlorophyl contains starch are left for a sufficient time in darkness, the starch is absorbed and completely disappears; but when they

are restored to the light the starch reappears in the chlorophyl of the cells.

With this dependence of assimilation on the presence of chlorophyl a new physiological division of labor is introduced into the life of plants. In the higher plants, while the work of assimilation is allocated to the chlorophyl-containing cells, that of cell division and growth devolves on another set of cells, which, lying deeper in the plant, are removed from the direct action of light, and in which chlorophyl is therefore never produced. In certain lower plants, in consequence of their simplicity of structure and the fact that all the cells are equally exposed to the influence of light, this physiological division of labor shows itself in a somewhat different fashion. Thus in some of the simple green algæ, such as *Spirogyra* and *Hydrodictyon*, assimilation takes place as in other cases during the day, while their cell division and growth takes place chiefly, if not exclusively, at night. Strasburger, in his remarkable observations on cell-divisions in *Spirogyra*, was obliged to adopt an artificial device in order to compel the *Spirogyra* to postpone the division of its cells to the morning.

Here the functions of assimilation and growth devolve on one and the same cell, but, while one of these functions is exercised only during the day, the time for the other is the night. It seems impossible for the same cell at the same time to exercise both functions, and these are here accordingly divided between different periods of the twenty-four hours.

The action of chlorophyl in bringing about the decomposition of carbonic acid is not, as was recently believed, absolutely confined to plants. In some of the lower animals, such as *Stentor* and other infusoria, the Green Hydra, and certain green planariæ and other worms, chlorophyl is differentiated in their protoplasm, and probably always acts here under the influence of light exactly as in plants.

Indeed, it has been proved* by some recent researches of Mr. Geddes, that the green planarias when placed in water and exposed to the sunlight give out bubbles of gas which contain from forty-four to fifty-five per cent. of oxygen. Mr. Geddes has further shown that these animals contain granules of starch in their tissues, and in this fact we have another striking point of resemblance between them and plants.

A similar approximation of the two organic kingdoms has been shown by the beautiful researches of Mr. Darwin—confirmed and extended by his son, Mr. Francis Darwin—on Drosera and other so-called carnivorous plants. These researches, as is now well known, have shown that in all carnivorous plants there is a mechanism fitted for the capture of living prey, and that the animal matter of the prey is absorbed by the plant after having been digested by a secretion which acts like the gastric juice of animals.

* "Sur la Fonction de la Chlorophyll dans les Planaires vertes," "Comptes Rendus," December, 1878.

Again, Nägeli has recently shown* that the cell of the yeast-fungus contains about two per cent. of peptine, a substance hitherto known only as a product of the digestion of azotized matter by animals.

Indeed, all recent research has been bringing out in a more and more decisive manner the fact that there is no dualism in life—that the life of the animal and the life of the plant are, like their protoplasm, in all essential points identical.

But there is, perhaps, nothing which shows more strikingly the identity of the protoplasm in plants and animals, and the absence of any deep-pervading difference between the life of the animal and that of the plant, than the fact that plants may be placed, just like animals, under the influence of anæsthetics.

When the vapor of chloroform or of ether is inhaled by the human subject, it passes into the lungs, where it is absorbed by the blood, and thence carried by the circulation to all the tissues of the body. The first to be affected by it is the delicate nervous element of the brain, and loss of consciousness is the result. If the action of the anæsthetic be continued, all the other tissues are in their turn attacked by it and their irritability arrested. A set of phenomena entirely parallel to these may be presented by plants.

We owe to Claude Bernard a series of interesting and most instructive experiments on the action of ether and chloroform on plants. He exposed to the vapor of ether a healthy and vigorous sensitive-plant, by confining it under a bell-glass into which he introduced a sponge filled with ether. At the end of half an hour the plant was in a state of anæsthesia. All its leaflets remained fully extended, but they showed no tendency to shrink when touched. It was then withdrawn from the influence of the ether, when it gradually recovered its irritability, and finally responded, as before, to the touch.

It is obvious that the irritability of the protoplasm was here arrested by the anæsthetic, so that the plant became unable to give a response to the action of an external stimulus.

It is not, however, the irritability of the protoplasm of only the motor elements of plants that anæsthetics are capable of arresting. These may act also on the protoplasm of those cells whose function lies in chemical synthesis, such as is manifested in the phenomena of the germination of the seed and in nutrition generally, and Claude Bernard has shown that germination is suspended by the action of ether or chloroform.

Seeds of cress, a plant whose germination is very rapid, were placed in conditions favorable to a speedy germination, and while thus placed were exposed to the vapor of ether. The germination, which would otherwise have shown itself by the next day, was arrested. For five or six days the seeds were kept under the influence of the ether, and

* "Ueber die chemische Zusammensetzung der Hefe," "Sitzungsbericht der math. phys. Classe der k.k. Akad. der Wissens. zu München," 1878.

showed during this time no disposition to germinate. They were not killed, however, they only slept; for, on the substitution of common air for the etherized air with which they had been surrounded, germination at once set in and proceeded with activity.

Experiments were also made on that function of plants by which they absorb carbonic acid and exhale oxygen, and which, as we have already seen, is carried on through the agency of the green protoplasm or chlorophyl, under the influence of light—a function which is commonly, but erroneously, called the respiration of plants.

Aquatic plants afford the most convenient subjects for such experiments. If one of these be placed in a jar of water holding ether or chloroform in solution, and a bell-glass be placed over the submerged plant, we shall find that the plant no longer absorbs carbonic acid or emits oxygen. It remains, however, quite green and healthy. In order to awaken the plant, it is only necessary to place it in non-etherized water, when it will begin once more to absorb carbonic acid, and exhale oxygen under the influence of sunlight.

The same great physiologist has also investigated the action of anæsthetics on fermentation. It is well known that alcoholic fermentation is due to the presence of a minute fungus, the yeast-fungus, the living protoplasm of whose cells has the property of separating solutions of sugar into alcohol, which remains in the liquid, and carbonic acid, which escapes into the air.

Now, if the yeast-plant be placed along with sugar in etherized water, it will no longer act as a ferment. It is anæsthesiated, and can not respond to the stimulus which, under ordinary circumstances, it would find in the presence of the sugar. If, now, it be placed on a filter, and the ether washed completely away, it will, on restoration to a saccharine liquid, soon resume its duty of separating the sugar into alcohol and carbonic acid.

Claude Bernard has further called attention to a very significant fact which is observable in this experiment. While the proper alcoholic fermentation is entirely arrested by the etherization of the yeast-plant, there still goes on in the saccharine solution a curious chemical change, the cane-sugar of the solution being converted into grape-sugar, a substance identical in its chemical composition with the cane-sugar, but different in its molecular constitution. Now, it is well known from the researches of Berthelot that this conversion of cane-sugar into grape-sugar is due to a peculiar inversive ferment, which, while it accompanies the living yeast-plant, is itself soluble and destitute of life. Indeed, it has been shown that, in its natural conditions, the yeast-fungus is unable of itself to assimilate cane-sugar, and that, in order that this may be brought into a state fitted for the nutrition of the fungus, it must be first digested and converted into grape-sugar, exactly as happens in our own digestive organs. To quote Claude Bernard's graphic account: "The fungus ferment has thus beside it

in the same yeast a sort of servant given by Nature to effect this digestion. The servant is the unorganized inversive ferment. This ferment is soluble, and, as it is not a plant, but an unorganized body destitute of sensibility, it has not gone to sleep under the action of the ether, and thus continues to fulfill its task."

In the experiment already recorded on the germination of seeds the interest is by no means confined to that which attaches itself to the arrest of the organizing functions of the seed, those namely which manifest themselves in the development of the radicle, and plumule, and other organs of the young plant. Another phenomenon of great significance becomes at the same time apparent: the anæsthetic exerts no action on the concomitant chemical phenomena which in germinating seeds show themselves in the transformation of starch into sugar under the influence of diastase (a soluble and non-living ferment which also exists in the seed), and the absorption of oxygen with the exhalation of carbonic acid. These go on as usual, the anæsthesiated seed continuing to respire, as proved by the accumulation of carbonic acid in the surrounding air. The presence of the carbonic acid was rendered evident by placing in the same vessel with the seeds which were the object of the experiment a solution of barytes, when the carbonate became precipitated from the solution in quantity equal to that produced in a similar experiment with seeds germinating in unetherized air.

So, also, in the experiment which proves that the faculty possessed by the chlorophyllian cells of absorbing carbonic acid and exhaling oxygen under the influence of light may be arrested by anæsthetics, it could be seen that the plant, while in a state of anæsthesia, continued to respire in the manner of animals; that is, it continued to absorb oxygen and exhale carbonic acid. This is the true respiratory function which was previously masked by the predominant function of assimilation, which devolves on the green cells of plants, and which manifests itself under the influence of light in the absorption of carbonic acid and the exhalation of oxygen.

It must not, however, be supposed that the respiration of plants is entirely independent of life. The conditions which bring the oxygen of the air and the combustible matter of the respiring plant into such relations as may allow them to act on one another are still under its control, and we must conclude that in Claude Bernard's experiment the anæsthesia had not been carried so far as to arrest such properties of the living tissues as are needed for this.

The quite recent researches of Schützenberger, who has investigated the process of respiration as it takes place in the cell of the yeast-fungus, have shown that vitality is a factor in this process. He has shown that fresh yeast, placed in water, breathes like an aquatic animal, disengaging carbonic acid, and causing the oxygen contained in the water to disappear. That this phenomenon is a function of the

living cell is proved by the fact that, if the yeast be first heated to 60° C. and then placed in the oxygenated water, the quantity of oxygen in the water remains unchanged; in other words, the yeast ceases to breathe.

Schützenberger has further shown that light exerts no influence on the respiration of the yeast-cell—that the absorption of oxygen by the cell takes place in the dark exactly as in sunlight. On the other hand, the influence of temperature is well marked. Respiration is almost entirely arrested at temperatures below 10° C., it reaches its maximum at about 40° C., while at 60° C. it again ceases.

All this proves that the respiration of living beings is identical, whether manifested in the plant or in the animal. It is essentially a destructive phenomenon—as much so as the burning of a piece of charcoal in the open air, and, like it, is characterized by the disappearance of oxygen and the formation of carbonic acid.

One of the most valuable results of the recent careful application of the experimental method of research to the life-phenomena of plants is thus the complete demolition of the supposed antagonism between respiration in plants and that in animals.

I have thus endeavored to give you in a few broad outlines a sketch of the nature and properties of one special modification of matter, which will yield to none other in the interest which attaches to its study, and in the importance of the part allocated to it in the economy of nature. Did the occasion permit, I might have entered into many details which I have left untouched; but enough has been said to convince you that in protoplasm we find the only form of matter in which life can manifest itself; and that, though the outer conditions of life —heat, air, water, food—may all be present, protoplasm would still be needed, in order that these conditions may be utilized; in order that the energy of lifeless nature may be converted into that of the countless multitudes of animal and vegetable forms which dwell upon the surface of the earth or people the great depths of its seas.

We are thus led to the conception of an essential unity in the two great kingdoms of organic nature—a structural unity, in the fact that every living being has protoplasm as the essential matter of every living element of its structure; and a physiological unity, in the universal attribute of irritability which has its seat in this same protoplasm, and is the prime mover of every phenomenon of life.

We have seen how little mere form has to do with the essential properties of protoplasm. This may shape itself into cells, and the cells may combine into organs in ever-increasing complexity, and protoplasm-force may be thus intensified, and, by the mechanism of organization, turned to the best possible account; but we must still go back to protoplasm as a naked, formless plasma if we would find—freed from all non-essential complications—the agent to which has

been assigned the duty of building up structure and of transforming the energy of lifeless matter into that of living.

To suppose, however, that all protoplasm is identical where no difference cognizable by any means at our disposal can be detected would be an error. Of two particles of protoplasm, between which we may defy all the power of the microscope, all the resources of the laboratory, to detect a difference, one can develop only to a jelly-fish, the other only to a man, and one conclusion alone is here possible—that deep within them there must be a fundamental difference which thus determines their inevitable destiny, but of which we know nothing, and can assert nothing beyond the statement that it must depend on their hidden molecular constitution.

In the molecular condition of protoplasm there is probably as much complexity as in the disposition of organs in the most highly differentiated organisms; and between two masses of protoplasm indistinguishable from one another there may be as much molecular difference as there is between the form and arrangement of organs in the most widely separated animals or plants.

Herein lies the many-sidedness of protoplasm; herein lies its significance as the basis of all morphological expression, as the agent of all physiological work, while in all this there must be an adaptiveness to purpose as great as any claimed for the most complicated organism.

From the facts which have been now brought to your notice there is but one legitimate conclusion—that life is a property of protoplasm. In this assertion there is nothing that need startle us. The essential phenomena of living beings are not so widely separated from the phenomena of lifeless matter as to render it impossible to recognize an analogy between them; for even irritability, the one grand character of all living beings, is not more difficult to be conceived of as a property of matter than the physical phenomena of radial energy.

It is quite true that between lifeless and living matter there is a vast difference, a difference greater far than any which can be found between the most diverse manifestations of lifeless matter. Though the refined synthesis of modern chemistry may have succeeded in forming a few principles which until lately had been deemed the proper product of vitality, the fact still remains that no one has ever yet built up one particle of living matter out of lifeless elements—that every living creature, from the simplest dweller on the confines of organization up to the highest and most complex organism, has its origin in preëxistent living matter—that the protoplasm of to-day is but the continuation of the protoplasm of other ages, handed down to us through periods of indefinable and indeterminable time.

Yet with all this, vast as the differences may be, there is nothing which precludes a comparison of the properties of living matter with those of lifeless.

When, however, we say that life is a property of protoplasm, we

assert as much as we are justified in doing. Here we stand upon the boundary between life in its proper conception, as a group of phenomena having irritability as their common bond, and that other and higher group of phenomena which we designate as consciousness or thought, and which, however intimately connected with those of life, are yet essentially distinct from them.

When the heart of a recently killed frog is separated from its body and touched with the point of a needle, it begins to beat under the excitation of the stimulus, and we believe ourselves justified in referring the contraction of the cardiac fibers to the irritability of their protoplasm as its proper cause. We see in it a remarkable phenomenon, but one nevertheless in which we can see unmistakable analogies with phenomena purely physical. There is no greater difficulty in conceiving of contractility as a property of protoplasm than there is of conceiving of attraction as a property of the magnet.

When a thought passes through the mind, it is associated, as we have now abundant reason for believing, with some change in the protoplasm of the cerebral cells. Are we, therefore, justified in regarding thought as a property of the protoplasm of these cells, in the sense in which we regard muscular contraction as a property of the protoplasm of muscle, or is it really a property residing in something far different, but which may yet need for its manifestation the activity of cerebral protoplasm?

If we could see any analogy between thought and any one of the admitted phenomena of matter, we should be justified in accepting the first of these conclusions as the simplest, and as affording an hypothesis most in accordance with the comprehensiveness of natural laws; but between thought and the physical phenomena of matter there is not only no analogy, but there is no conceivable analogy; and the obvious and continuous path which we have hitherto followed up in our reasonings from the phenomena of lifeless matter through those of living matter here comes suddenly to an end. The chasm between unconscious life and thought is deep and impassable, and no transitional phenomena can be found by which as by a bridge we may span it over; for even from irritability, to which, on a superficial view, consciousness may seem related, it is as absolutely distinct as it is from any of the ordinary phenomena of matter.

It has been argued that because physiological activity must be a property of every living cell, psychical activity must be equally so, and the language of the metaphysician has been carried into biology, and the "cell-soul" spoken of as a conception inseparable from that of life.

That psychical phenomena, however, characterized as they essentially are by consciousness, are not necessarily coextensive with those of life, there can not be a doubt. How far back in the scale of life consciousness may exist we have as yet no means of determining, nor

is it necessary for our argument that we should. Certain it is that many things, to all appearance the result of volition, are capable of being explained as absolutely unconscious acts; and when the swimming swarm-spore of an alga avoids collision, and, by a reversal of the stroke of its cilia, backs from an obstacle lying in its course, there is almost certainly in all this nothing but a purely unconscious act. It is but a case in which we find expressed the great law of the adaptation of living beings to the conditions which surround them. The irritability of the protoplasm of the ciliated spore responding to an external stimulus sets in motion a mechanism derived by inheritance from its ancestors, and whose parts are correlated to a common end—the preservation of the individual.

But even admitting that every living cell were a conscious and thinking being, are we therefore justified in asserting that its consciousness, like its irritability, is a property of the matter of which it is composed? The sole argument on which this view is made to rest is that from analogy. It is argued that because the life-phenomena, which are invariably found in the cell, must be regarded as a property of the cell, the phenomena of consciousness by which they are accompanied must be also so regarded. The weak point in the argument is the absence of all analogy between the things compared, and, as the conclusion rests solely on the argument from analogy, the two must fall to the ground together.

In a lecture* to which I once had the pleasure of listening—a lecture characterized no less by lucid exposition than by the fascinating form in which its facts were presented to the hearers—Professor Huxley argues that no difference, however great, between the phenomena of living matter and those of the lifeless elements of which this matter is composed should militate against our attributing to protoplasm the phenomena of life as properties essentially inherent in it; since we know that the result of a chemical combination of physical elements may exhibit physical properties totally different from those of the elements combined; the physical phenomena presented by water, for example, having no resemblance to those of its combining elements, oxygen and hydrogen.

I believe that Professor Huxley intended to apply this argument only to the phenomena of life in the stricter sense of the word. As such it is conclusive. But when it is pushed further, and extended to the phenomena of consciousness, it loses all its force. The analogy, perfectly valid in the former case, here fails. The properties of the chemical compound are like those of its components, still physical properties. They come within the wide category of the universally accepted properties of matter, while those of consciousness belong to a category absolutely distinct—one which presents not a trace of a connection with any of those which physicists have agreed in assign-

* "The Physical Basis of Life" (see "Essays and Reviews," by T. H. Huxley).

ing to matter as its proper characteristics. The argument thus breaks down, for its force depends on analogy alone, and here all analogy vanishes.

That consciousness is never manifested except in the presence of cerebral matter or of something like it, there can not be a question; but this is a very different thing from its being a property of such matter in the sense in which polarity is a property of the magnet, or irritability of protoplasm. The generation of the rays which lie invisible beyond the violet in the spectrum of the sun can not be regarded as a property of the medium which by changing their refrangibility can alone render them apparent.

I know that there is a special charm in those broad generalizations which would refer many very different phenomena to a common source. But in this very charm there is undoubtedly a danger, and we must be all the more careful lest it should exert an influence in arresting the progress of truth, just as at an earlier period traditional beliefs exerted an authority from which the mind but slowly and with difficulty succeeded in emancipating itself.

But have we, it may be asked, made in all this one step forward toward an explanation of the phenomena of consciousness or the discovery of its source? Assuredly not. The power of conceiving of a substance different from that of matter is still beyond the limits of human intelligence, and the physical or objective conditions which are the concomitants of thought are the only ones of which it is possible to know anything, and the only ones whose study is of value.

We are not, however, on that account forced to the conclusion that there is nothing in the universe but matter and force. The simplest physical law is absolutely inconceivable by the highest of the brutes, and no one would be justified in assuming that man had already attained the limit of his powers. Whatever may be that mysterious bond which connects organization with psychical endowments, the one grand fact—a fact of inestimable importance—stands out clear and freed from all obscurity and doubt, that from the first dawn of intelligence there is with every advance in organization a corresponding advance in mind. Mind as well as body is thus traveling onward through higher and still higher phases; the great law of evolution is shaping the destiny of our race; and though now we may at most but indicate some weak point in the generalization which would refer consciousness as well as life to a common material source, who can say that in the far-off future there may not yet be evolved other and higher faculties from which light may stream in upon the darkness, and reveal to man the great mystery of thought?

JOHN STUART MILL.

By ALEXANDER BAIN, LL. D.,
PROFESSOR OF LOGIC IN THE UNIVERSITY OF ABERDEEN.

III.

MY acquaintance with Mill dates from 1839, when I was a student at Marischal College, Aberdeen. In the winter of 1838–'39, John Robertson, who was then assisting in the Review, paid a short visit to his native city. I had known him when I was a child, but had not seen him for years. He asked me to meet him, and entered into free conversation about his doings in London, and about my pursuits and prospects. He gave me both advice and encouragement, and spoke a good deal about Mill, whom I had never heard of, although I may have known something of his father. On returning to London, Robertson mentioned my name to Mill. In the summer of 1839 I wrote a criticism of some points in Herschel's "Discourse on Natural Philosophy," a book that had long fascinated me, as it had done so many others. I thought Herschel occasionally weak in his metaphysics, and directed my criticism to some of those weaknesses. Robertson showed Mill this paper. He spoke favorably of the effort, but remarked to me afterward that the criticism was too severe, and that the book "always seemed to him to have the characters of a first crude attempt of a clever and instructed man in a province new to him."

In 1840 I took my M. A. degree, and began to write for periodicals. Mill had just parted with the "London and Westminster": but through Robertson, I got my first published article admitted into the "Westminster" for September; an exposition of the two scientific novelties—the electrotype and daguerreotype. In July, 1841, was published a second article entitled "The Properties of Matter," to which I owed the first notice taken of me by Mr. Grote. Both these articles did me good with Mill. In the same autumn (1841) Robertson, who was now very much at sea himself, came down to Aberdeen, and made a long stay; during which I had abundant talk with him, my early friend David Masson being also of the party. Robertson occasionally wrote to Mill, and at last incited me to write to him. I scarcely remember anything of the terms of the letter, but I have preserved his reply, dated 21st September, 1841. After my first meeting with Robertson, nearly three years previous, I assiduously perused the back numbers of the "London" and "London and Westminster" Reviews, as well as each new number as it appeared, whereby I became thoroughly familiarized with Mill's ideas, and was thus able to exchange ideas with him on his own subjects. I was engaged for the succeed-

ing winter to teach the class of moral philosophy in Marischal College, as substitute for the Professor; and his letter is chiefly a comment upon this fact. Notwithstanding that he was then intently occupied in finishing his "Logic" for the press, he wrote me several other letters in the course of the winter. In the one immediately following (October 15th), he made mention of Comte, in these terms: "Have you ever looked into Comte's 'Cours de Philosophie Positive'? He makes some mistakes, but on the whole I think it very nearly the grandest work of this age." From the remaining letters, I can gather that I had written him a good deal upon Whewell's writings, as well as on Herschel, and on his own coming book. Among other things, he sketched out for me a course of reading on political and historical philosophy. He also criticised in detail the strong and weak points of an article published by me in the "Westminster" in January, 1842, with the somewhat misleading title—"Toys."

As soon as the Aberdeen winter session was over, in the middle of April, 1842, I went to London, and remained there five months. The day after arriving I walked down to the India House with Robertson, and realized my dream of meeting Mill in person. I am not likely to forget the impression he made upon me as he stood by his desk, with his face turned to the door as we entered. His tall, slim figure, his youthful face and bald head, fair hair and ruddy complexion, and the twitching of his eyebrow when he spoke, first arrested the attention: then the vivacity of his manner, his thin voice approaching to sharpness, but with nothing shrill or painful about it, his comely features and sweet expression—would have all remained in my memory, though I had never seen him again. To complete the picture, I should add his dress, which was constant—a black dress-suit, with silk necktie. Many years after that he changed his dress-coat for a surtout; but black cloth was his choice to the end.

My opportunities of conversation with him for these five months consisted in going down to the India House twice a week at four o'clock, and walking with him a good part of his way to Kensington Square, where his mother and family lived. I also spent occasional evenings at the house, where I met other friends of his—G. H. Lewes being a frequent visitor. I may be said to have traveled over a good part of his mind that summer: although he did not then give me his full confidence in many things that I came to know afterward. I had a very full acquaintance with his views on philosophy and politics, as well as a complete appreciation of his whole manner of thinking.

His "Logic" was finished and ready for press; he had intended that it should be out in April of that year (1842). He had submitted it the previous winter to Mr. John Murray, who kept it for some time, and then declined it, so that it could not be brought out that season. He then submitted it to J. W. Parker, by whom it was

eagerly accepted.* I do not remember the date of Parker's acceptance, but the book had not begun to go to press in the summer months; the printing actually took place in the following winter. One of the first results of our conversations was that he gave me the manuscript to peruse. During my stay I read and discussed with him the whole of it.

The impression made upon me by the work was, as may be supposed, very profound. I knew pretty well the works that could be ranked as its precursors in inductive logic, but the difference between it and them was obviously vast. The general impression at first overpowered my critical faculties; and it was some time before I could begin to pick holes. I remember, among the first of my criticisms, remarking on the chapter on "Things denoted by Names" as not being very intelligible; I had at the same time a difficulty in seeing its place in the scheme, although I did not press this objection. The effect was that he revised the chapter, and introduced the subordinate headings, which very much lightened the burden of its natural abstruseness.

The main defect of the work, however, was in the experimental examples. I soon saw, and he felt, as much as I did, that these were too few and not unfrequently incorrect. It was on this point that I was able to render the greatest service. Circumstances had made me tolerably familiar with the experimental physics, chemistry, and physiology of that day, and I set to work to gather examples from all available sources. Liebig's books on the application of chemistry had then just appeared, and contained many new and striking facts and reasonings, which we endeavored to turn to account: although at the present day some of those inductions of his have lost their repute. An Aberdeen lecturer on chemistry, the late Dr. John Shier (chemist to the colony of Demerara) went carefully over with me all the chemical examples, and struck out various erroneous statements. I had recently made a study of Faraday's very stiff papers on electricity, and from these I extracted one generalization, somewhat modified by myself, and this Mill prized very highly; nevertheless, it was afterward carped at by Whewell, as going beyond what Faraday would have allowed. One way or other, I gave him a large stock of examples to choose from, as he revised the third book for the press. The difficulty that was most felt was to get good examples of the *purely experimental* methods. He had availed himself of the famous research on dew adduced by Herschel. There was hardly to be got any other example so good. For one of his later editions I gave him the example from

* So great a work can sustain even a little anecdote. Parker, in intimating his willingness to publish the book, sent the opinion of his referee, in the writer's own hand, withholding the name. "He forgot," said Mill, "that I had been an editor, and knew the handwriting of nearly every literary man of the day." The referee was Dr. W. Cooke Taylor, who afterward was one of the reviewers of the book.

Brown-Séquard, on the causes of cadaveric rigidity, and also used it in my own book. For the deductive method, and the allied subjects of explanation and empirical and derivative law, the examples that we found were abundant. When, however, I suggested his adopting some from psychology, he steadily, and I believe wisely, resisted; and, if he took any of these, it was in the deductive department.

I was so much struck with the view of induction that regarded it as reasoning from particulars to particulars, that I suggested a further exemplification of it in detail, and he inserted two pages of instances that I gave him. On the last three books I had little to offer. I remember his saying, at a later period, that the fourth book (which I have always regarded as the crude materials of a logic of definition and classification) was made up of a number of subjects that he did not know where to place.

The "Logic" has been about the best attacked book of the time; and the author has in successive editions replied to objections and made extensive amendments. I have had myself full opportunities for expressing both agreements and dissents in regard to all the main points. Yet I could not pretend to say that criticism has been exhausted, or that imperfections and even inconsistencies may not even yet be pointed out. It is long since I was struck with the seeming incompatibility between the definition of logic in the introduction—viz., the science of proof, or evidence—and the double designation in the title—Principles of Evidence and the Methods of Scientific Investigation. Previous writers laid little stress on proof, and Mill took the other extreme and made proof everything. Bacon, Herschel, and Whewell seemed to think that, if we could only make discoveries, the proof would be readily forthcoming—a very natural supposition with men educated mainly in mathematics and physics. Mill, from his familiarity with the moral and political sciences, saw that proof was more important than discovery. But the title, although larger than the definition, is not larger than the work; he did discuss the methods of investigation, as aids to discovery, as well as means of proof; only, he never explained the mutual bearings of the two. Any one that tries will find this not an easy matter.

The sixth book was the outcome of his long study of politics, both practical and theoretical, to which the finishing stroke was given by the help of Auguste Comte. I will return to this presently.

In five months he carried the work through the press, and brought it out in March, 1843. We may form some estimate of the united labor of correcting proof-sheets, often one a day, of reconsidering the new examples that have been suggested, of reading Liebig's two books, and Comte's sixth volume (nearly a thousand pages), and of recasting the concluding chapters. From the moment of publication, the omens were auspicious. Parker's trade-sale was beyond his anticipations, and the book was asked for by unexpected persons, and appeared in

shop-windows where he never thought to see it. Whately spoke handsomely of it, and desired his bookseller to get an additional copy for him, and expose it in the window.

While the work was printing, I prepared from the sheets a review of it, which came out in the "Westminster" in the April number, and was even more laudatory than Mill liked. The first adverse criticism of importance was an article in the autumn number of the "British Critic," of nearly a hundred pages, known to have been written by Mr. W. G. Ward, the ally of Newman and Pusey. It was a most remarkable production, and gave Mill very great satisfaction, all things considered. It was not so much a review of the "Logic" as of Mill altogether. Mr. Ward had followed him through his various articles in the "London and Westminster," and had mastered his modes of thinking in all the great questions; and the present article takes these up along with the "Logic." He expresses a warm interest in Mill himself, remarking, "An inquirer, who bears every mark of a single-minded and earnest pursuit of truth, cheers and relieves the spirits"; a pretty strong innuendo as to the prevailing dispositions of so-called inquirers. He deplores Mill's "miserable moral and religious deficiencies," and says if his "principles be adopted as a full statement of the truth, the whole fabric of Christian theology must totter and fall." Accordingly, the article is devoted to counterworking these erroneous tendencies; and the parts chosen for attack are the experience-foundations of the mathematical axioms, the derived view of conscience, and necessity as against free-will. Mr. Ward has continued to uphold his peculiar tenets against the experience-school. He had afterward, as he informs me, a good deal of correspondence with Mill, and once met him. At his instigation, Mill expunged from his second edition an objectionable anecdote.*

Without pursuing further at present the fortunes of the "Logic," I will allude to the connection between Mill and Comte, and to the share that Comte had in shaping Mill's political philosophy. Wheatstone always claimed to be the means of introducing Comte in England. He brought over from Paris the first two volumes of the "Philosophie Positive," after the publication of the second, which was in 1837. It would appear that the first volume, by itself, published in 1830, had fallen dead; notwithstanding that the first two chapters really contained in very clear language, although without expansion, the two great foundations that Comte built upon—the Three Stages and the Hierarchy of the Sciences. Wheatstone mentioned the work to his scientific friends in London, and among others to Brewster, who was then a contributor of scientific articles to the "Edinburgh Re-

* In regard to the "British Critic," he wrote, "I always hailed Puseyism, and predicted that thought would sympathize with thought—though I did not expect to find my own case so striking an example." I was told that he had written several letters in the "Morning Chronicle" in this strain of subtile remark.

view." Comte's volumes struck him at once as a good topic; and he wrote an article on them in the August number for 1838. Any one knowing him would have predicted as the strain of his review an indignant or else contemptuous exposure of the atheism, a fastening on the weak points in his own special subjects, as optics, and a cold recognition of his systematic comprehensiveness. This, however, was to leave out of the account one element—his antipathy to Whewell; sufficiently marked in a review of the "History of the Inductive Sciences" in the previous year. He found with joy a number of observations on hypothesis and other points, that he could turn against Whewell, and the effect was, I have no doubt, to soften the adverse criticisms, and to produce an article on the whole favorable to the book, and one that even Comte himself regarded with some complacency. Mill got wind of the two volumes in the end of 1837, after he had completed the draft of his book on Induction. The "Autobiography" gives (pp. 210–214) the general effect produced upon him by the whole work, which he perused with avidity as the successive volumes appeared; but does not adequately express the influence in detail, nor the warmth of esteem and affection displayed in the five years of their correspondence from 1841 to 1846. In our many conversations during the summer of 1842, Mill occasionally mentioned Comte, but not in a way to give me any clear conception of what his merits consisted in. Among his associates at that time was William Smith, lately dead, and known as the author of "Thorndale" and various other works. He was a pupil of the Mills in philosophy, and occupied himself in contributing to magazines. In the winter of that year, he wrote a review of Comte in "Blackwood" (March, 1843), giving very well-selected extracts; and from these I derived my first impression of the peculiar force of the book. I remember particularly being struck with the observations on the metaphysical and critical stage, as a vein of remark quite original.

It was in the summer of that year (1843) that I read the work for myself. I was in London as before, and had the same opportunities of conversing with Mill. We discussed the work chapter by chapter, up to the last volume, which I had not begun when I left town. We were very much at one, both as to the merits and as to the defects of the work. The errors were mostly of a kind that could be remedied by ordinary men better informed on special points than Comte; while the systematic array was untouched. The improvement effected in the classification of the sciences was apparent at a glance; while the carrying out of the hierarchy, involving the dependence of each science upon the preceding, first as to doctrine, and next as to method, raised the scheme above the usual barrenness of science-classifications. Mill had already seized with alacrity, and embodied in the "Logic," Comte's great distinction between social statics and social dynamics; and I was even more strongly impressed than he respecting the value of

that distinction as an instrument of social analysis. Comte, according to his plan of pushing forward the ideas of each of the fundamental sciences into the succeeding, had taken up the distinction in abstract mechanics, and carried it first into biology, where it made his contrast between anatomy and physiology—structure and function. The next step was to sociology, and led to the distinction of order and progress. I confess that I never thought the three cases exactly parallel; still, however the distinction came, it was invaluable in sociology; and Comte's separation of the two interests—social order and social progress—was a grand simplification of the subject, and a mighty advance upon the historical and political philosophy of his predecessors and contemporaries. The social statics he discussed briefly, as compared with the magnitude of the topics, but indicated well enough what these topics were; the social dynamics enabled him to give free scope to his doctrine of the Three Stages, and carry this out in a grand survey of the historical development of mankind. Here, of course, he exposed a wide front to criticism; but, while numerous exceptions might be taken to his interpretations of history, it was truly wonderful to see how many facts seemed to fall in happily under his formulas. Mill, it will be seen from the "Logic" (book vi., chapter x.), accepted the Three Stages as an essential part of Comte's historical method, which method he also adopts and expounds as the completion of the logic of sociology. In our very first conversations, I remember how much he regretted Comte's misappreciation of Protestantism; and he strove in the early part of their correspondence to make him see this. He also endeavored to put him right on the specialty of England in the political evolution.

It is curious to observe that his altered estimate of Comte never extended to the views appropriated from him on the method of social science. The modifications in the later editions consisted mainly in leaving out the high-pitched compliments to Comte in the first; none of the quotations are interfered with. I give a few examples of these omissions. Referring to the latest edition, the eighth, on page 490, he writes: "The only thinker who, with a competent knowledge of scientific methods in general"; in the first edition—"The greatest living authority on scientific methods in general." On page 506, line five from bottom, before "To prove (in short)," the first edition has—"It is therefore well said of M. Comte." In page 512, line thirteen from top, the words "but deem them" are followed in the first edition by "with the single exception of M. Comte." In page 513, line nine from top, after "up to the present time," a long sentence of reference to Comte is left out. In page 530, line fourteen from top, after "attempting to characterize," there is omitted the clause—"but which hitherto are to my knowledge exemplified nowhere but in the writings of M. Comte."

The distinction of statics and dynamics was carried by Mill into

the plan of his "Political Economy." It also entered into his "Representative Government"; and, if he had written a complete work on sociology, he would have made it the basis of his arrangement as Comte did.

Mill's correspondence with Comte began in 1841. I heard from himself a good deal of the substance of it as it went on. Comte's part being now published, we can judge of the character of the whole, and infer much of Mill's part in the work. In 1842 and 1843 the letters on both sides were overflowing with mutual regard. It was Comte's nature to be very frank, and he was circumstantial and minute in his accounts of himself and his ways. Mill was unusually open; and revealed, what he seldom told to anybody, all the fluctuations in his bodily and mental condition. In one of the early letters, he coined the word "pedantocracy," which Comte caught up, and threw about him right and left, ever after. Already in 1842 troubles were brewing for him in Paris, partly in consequence of his peculiar tenets, and still more from his unsparing abuse of the notables of Paris, the foremost object of his hate being the all-powerful Arago. His personal situation, always detailed with the utmost fullness, makes a considerable fraction of the correspondence on his side. When in 1843 the "Polytechnic pedantocracy," that is to say, the Council of the Polytechnic School, for which he was examiner, first assumed a hostile attitude, and when his post was in danger, Mill came forward with an offer of pecuniary assistance, in case of the worst; the generosity of this offer will be appreciated when I come to state what his own circumstances were at that moment. Comte, however, declined the proposal; he would accept assistance from men of wealth among his followers; indeed, he broadly announced that it was their duty to minister to his wants; but he did not think that philosophers should have to devote their own small means to helping one another. Mill sent the "Logic" to him as soon as published; he is overjoyed at the compliments to himself, and warmly appreciates Mill's moral courage in owning his admiration. They discuss sociological questions at large, at first with considerable cordiality and unanimity; but the harmony is short-lived. In the summer of 1843 begins the debate on women, which occupied the remainder of that year; the letters being very long on both sides. By November, Comte declares the prolongation of the discussion needless; but protests strongly against Mill's calling women "slaves." Mill copied out the letters on both sides, and I remember reading them. Some years later, when I asked him to show them to a friend of mine, he consented, but said that, having reread them himself, he was dissatisfied with the concessions he had made to Comte, and would never show them to any one again. What I remember thinking at the time I read them was, that Mill needlessly prolonged the debate, hoping against hope to produce an impression upon Comte. The correspondence was not arrested by this divergence, nor was

Mill's sympathy for Comte's misfortunes in any way abated; but the chance of their ever pulling together on social questions was reduced to a very small amount. They still agreed as to the separation of the spiritual and the temporal power, but only as a vague generality. In July, 1844, came the crash at the Polytechnic; by a dexterous manœuvre, Comte was ousted without being formally dismissed; he lost six thousand francs a year, and was in dire distress. He appealed to Mill, but with the same reservation as before; Mill exerted himself with Grote and Molesworth, who with Raikes Currie agreed to make up the deficiency for the year. Another election came round, and he was not reinstated, and was again dependent on the assistance of his English friends. They made up a portion of his second year's deficiency, but declined to continue the grant. He is vexed and chagrined beyond measure, and administers to Mill a long lecture upon the relations of rich men to philosophers; but his complaint is most dignified in its tone. This puts Mill into a very trying position; he has to justify the conduct of Grote and Molesworth, who might with so little inconvenience to themselves have tided him over another year. The delicate part of the situation was that Grote, who began admiring Comte, as Mill did, although never to the same degree, was yet strongly adverse to his sociological theories, especially as regarded their tendency to introduce a new despotism over the individual. Indeed, his admiration of Comte scarcely extended at all to the sociological volumes. He saw in them frequent mistakes and perversions of historical facts, and did not put the same stress as Mill did upon the social analysis — the distinction of statics and dynamics, and historical method; in fact, he had considerable misgivings throughout as to all the grand theories of the French school in the philosophy of history. But the repression of liberty by a new machinery touched his acutest susceptibility; he often recurred in conversation to this part of Comte's system, and would not take any comfort from the suggestion I often made to him that there was little danger of any such system ever being in force. It was the explanation of this divergence that Mill had to convey to Comte; who, on the other hand, attempted in vain to reargue the point by calling to mind how much he and Mill were agreed upon, which, however, did not meet Grote's case. He returned to the theme in successive letters, and urged upon Mill that there was an exaggeration of secondary differences, and so on. What may be said in his favor is that Grote turned round upon him rather too soon. This was in 1846. The same year his Clotilde died. He still unfolded his griefs to Mill, and, as may be supposed, received a tender and sympathizing response. The correspondence here ends.*

* Although Mill was the first and principal medium of making Comte and his doctrines familiar to the public, he was soon followed by George Henry Lewes, who was beginning his literary career, as a writer in reviews, about the year 1841. I met Lewes frequently when I was first in London in 1842. He sat at the feet of Mill, read the

I must still come back to the year 1842. In the October number of the "Westminster Review" for that year was published his article on Bailey's "Theory of Vision," in which he upheld the Berkeleian doctrine against Bailey's attacks. I remember his saying that he went to the country, on one occasion, from Friday till Tuesday, and in the three days wrote this article. With all his respect for Bailey, he used a number of expressions very derogatory to his understanding; attributing to him such things as a "triumphing over a shadow," "misconceiving the argument he was replying to," etc. Bailey was much hurt at the time by these expressions; and Mill's reply on this point is very characteristic ("Dissertations," ii., 119): "To dispute the soundness of a man's doctrines and the conclusiveness of his arguments, may always be interpreted as an assumption of superiority over him; true courtesy, however, between thinkers, is not shown by refraining from this sort of assumption, but by tolerating it in one another; and we claim from Mr. Bailey this tolerance, as we, on our part, sincerely and cheerfully concede to him the like." This was his principle of composition throughout his polemical career, and he never departed from it. Of Bailey's reply on this occasion, he remarked: "The tone of it is peevish. But Bailey is, I know, of that temper—or rather I infer it from sundry indications."

ATLANTIS NOT A MYTH.

By EDWARD H. THOMPSON.

OUR sturdy worker in the copper mines of Lake Superior, finding both himself and his vein of copper growing poorer day by day, determines to seek some more paying claim in the as yet unexplored portion of the copper country. He gathers his kit of tools together and starts, and, after many a hard hour's travel over the wild and rugged country, finds a region with abundant signs of copper, and where seemingly no human foot has trod since creation's dawn.

He strikes a rich vein and goes steadily to work digging and blasting his way to the richer portions, when suddenly, right in the richest part, he finds his lead cut off by what looks to his experienced eye marvelously like a mining shaft. Amazedly he begins to clear out of the pit the fallen earth and the *débris* of ages, and the daylight thus let in reveals to his astonished gaze an immense mass of copper raised

"Logic" with avidity, and took up Comte with equal avidity. These two works, I believe, gave him his start in philosophy; for, although he had studied in Germany for some time, I am not aware that he was much impressed by German philosophy. In an article in the "British and Foreign Review," in 1843, on the modern philosophy of France, he led up to Comte, and gave some account of him.

some distance from the original bottom of the pit on a platform of logs, while at his feet lie a number of strange stone and copper implements—some thin and sharp like knives and hatchets, others huge and blunt like mauls and hammers—all being left in such a manner as though the workman had but just gone to dinner and might be expected back at any moment. Bewildered, he ascends to the surface again and looks about him. He sees mounds that from their positions are evidently formed from the refuse of the pit, but these mounds are covered with gigantic trees, evidently the growth of centuries; and, looking still closer, he sees that these trees are fed from the decayed ruins of trees still older—trees that have sprung up, flourished, grown old, and died since this pit was dug or these mounds were raised. The more he thinks of the vast ages that have elapsed since this pit was dug, that mass of copper quarried and raised, the more confused he becomes: his mind can not grasp this immensity of time.

"Who were these miners? When did they live, and where did they come from?" are the questions he asks himself, but gets no answer. However, one fact is patent to him—that, whoever they were, they will not now trouble his claim; and, consoled by this reflection, he goes to work again.

The traveler in wandering through the dense and almost impenetrable forests of Central and South America, suddenly finds himself upon a broad and well-paved road, but a road over which in places there have grown trees centuries old. Curiously following this road, he sees before him, as though brought thither by some Aladdin's lamp, a vast city, a city built of stone—buildings that look at a distance like our large New England factories—splendid palaces and aqueducts, all constructed with such massiveness and grandeur as to compel a cry of astonishment from the surprised traveler—an immense but deserted city, whose magnificent palaces and beautiful sculpturing are inhabited and viewed only by the iguana and centiped. The roads and paths to the aqueducts, once so much traveled as to have worn hollows in the hard stone, are now trodden only by the ignorant mestizo or simple Indian. Of this deserted home of a lost race, the traveler asks the same question as the miner, and the only answer he gets from the semi-civilized Indian is a laconic "*Quien sabe?*" And who does know?

The curious and scientific world, however, are not so easily answered, and various are the theories and conjectures as to these diggers of mines and builders of mounds and strange cities. One of the most plausible of these — one believed by many scientists to be the true theory—is this: Ages ago the Americas presented a very different appearance from what they now do. Then an immense peninsula extended itself from Mexico, Central America, and New Granada, so far into the Atlantic that Madeira, the Azores, and the West India Islands are now fragments of it. This peninsula was a fair and fertile country inhabited by rich and civilized nations, a people versed in the arts

of war and civilization—a country covered with large cities and magnificent palaces, their rulers according to tradition reigning not only on the Atlantic Continent, but over islands far and near, even into Europe and Asia. Suddenly, without warning, this whole fair land was ingulfed by the sea, in a mighty convulsion of nature.

Now, this catastrophe is not impossible or even improbable. Instances are not wanting of large tracts of land, several hundred miles in extent, disappearing in a like manner. The island of Ferdinandea suddenly appeared, and after a while as suddenly disappeared. In 1819, during an earthquake in India, an immense tract of land near the river Indus sank from view, and a lake now occupies its place.

The whole bed of the Atlantic, where Atlantis is said to have been situated, consists of extinct volcanoes. The terrible Lisbon earthquake of 1755, and the later American shock, created a commotion throughout the whole Atlantic area.

That Atlantis possessed great facilities for making a sudden exit can not be doubted. Its very situation gives good color to the narratives of ancient Grecian historians and Toltecian traditions, that "it disappeared by earthquakes and inundations."

Not only is it within the bounds of possibility that it might have occurred, but if traditions so clear and distinct as to be almost authentic history are to be believed, then it did occur. Listen to what one of the most cautious of ancient writers, Plato, says: "Among the great deeds of Athens, of which recollection is preserved in our books, there is one that should be placed above all others. Our book tells us that the Athenians destroyed an army that came across the Atlantic seas, and insolently invaded Europe and Asia, for this sea was then navigable; and beyond the straits where you place the Pillars of Hercules was an immense island, larger than Asia and Libya combined. From this island one could pass easily to the other islands, and from these to the continent beyond. The sea on this side of the straits resembled a harbor with a narrow entrance, but there is a veritable sea, and the land which surrounds it is a veritable continent. On this island of Atlantis there reigned three kings with great and marvelous power. They had under their domain the whole of Atlantis, several of the other islands, and part of the continent. At one time their power extended into Europe as far as Tyrrhenia, and uniting their whole force they sought to destroy our country at a blow, but their defeat stopped the invasion and gave entire freedom to the countries this side of the Pillars of Hercules. Afterward, in one day and one fatal night, there came mighty earthquakes and inundations, that ingulfed that warlike people. Atlantis disappeared, and then that sea became inaccessible, on account of the vast quantities of mud that the ingulfed island left in its place." It is possible that the *débris*, said to have been left by this catastrophe, might be identical with or the nuclei of the *sargazo* fields that, many centuries later,

Columbus found almost impenetrable. Again, Plato, in an extract from Proclus, speaks of an island in the Atlantic whose inhabitants preserved knowledge from their ancestors of a large island in the Atlantic, which had dominion over all other islands of this sea.

Plutarch, in his life of the philosopher Solon, Herodotus, and other ancient writers, speak of this island as a known fact, and it is impossible to believe otherwise than that Seneca thought of Atlantis when he writes in his tragedy of "Medea": "Late centuries will appear, when the ocean's veil will lift to open a vast country. New worlds will Thetsys unveil. Ultima Thule" (Iceland) "will not remain the earth's boundary." He evidently believed in the unknown island and continent, and knew it would not remain for ever unknown.

Diodorus Siculus says that "opposite to Africa lies an island which, on account of its magnitude, is worthy to be mentioned. It is several days distant from Africa. It has a fertile soil, many mountains, and not a few plains, unexcelled in their beauty. It is watered by many navigable rivers, and there are to be found estates in abundance adorned with fine buildings." Again he says, "Indeed, it appears on account of the abundance of its charms as though it were the abode of gods and not of men."

The situation, the description of the country, in fact every particular, agrees precisely with our idea of Atlantis; and what other land now in existence agrees in any way with this description—what islands of magnitude that contain navigable rivers, large fertile plains, and mountains?

Turning from our well-known ancient writers, we find in all the traditions and books of the ancient Central Americans and Mexicans a continual recurrence to the fact of an awful catastrophe, similar to that mentioned by Plato and others.

Now, what are we to believe? This, that either the traditions and narratives of these ancient writers and historians of both lands are but a tissue of fabrications, evolved from their own brains, with perhaps a small thread of fact, or else that they are truths, and truths proving that the Americas, instead of being the youngest habitation of man, are among the oldest, if not, as De Bourbourg affirms, the oldest.

Brasseur de Bourbourg, who Baldwin says has studied the monuments, writings, and traditions left by this civilization more carefully and thoroughly than any man living, is an advocate of this theory, and to him are we indebted for most of our translations of the traditions and histories of the ancient Americans.

To the imaginative and lovers of the marvelous, this theory is peculiarly fascinating, and the fact that there is plausible evidence of its truth adds to the effect. With their mind's eye they can see the dreadful events, as recorded by Plato, as in a panorama. They see the fair and fertile country, filled with people, prosperous and happy; the sound of busy life from man and beast fills the air. Comfort and prosperity

abound. The sun shines clear overhead, and the huge mountains look down upon the cities and villages at their feet, like a mother upon her babes: all is a picture of peacefulness. Suddenly, in a second, all is changed. The protecting angels become destroying fiends, vomiting fire and liquid hell upon the devoted cities at their feet, burning, scorching, strangling their wretched inhabitants. The earth rocks horribly, palaces, temples, all crashing down, crushing their human victims, flocked together like so many ants. Vast rents open at their very feet, licking with huge, flaming tongues the terrified people into their yawning mouths. And then the inundations. Mighty waves sweep over the land. The fierce enemies, Fire and Water, join hands to effect the destruction of a mighty nation.

How they hiss and surge, rattle and seethe! How the steam rises, mingled with the black smoke, looking like a mourning-veil, that it is, and, when that veil is lifted, all is still, the quiet of annihilation! Of all that populous land, naught remains save fuming, seething mud. It is not to be supposed that all perished in that calamity. Long before this they had spread over the portion of the Americas contiguous to the peninsula, building cities, palaces, roads, and aqueducts, like those of their native homes; and adventurous pioneers continually spreading north, east, and westward, their constant increase of numbers from their former homes enabling them to overcome the resistance offered to their progress by both natives and nature, till at last they reached and discovered the copper country of Lake Superior. That they appreciated this discovery is evinced by the innumerable evidences of their works and of their skill in discovering the richest and most promising veins. Wherever our miners of the present day go, they find their ancient fellow craftsmen have been before them, worked the richest veins and gathered the best copper; and it is supposed that they continued thus till the terrible blotting out of their native country cut short all this, and left this advancing civilization to wither and die like a vine severed from the parent stem.

Having no further accession to their numbers, and being continually decimated by savages and disease, they slowly retreated before the ever-advancing hordes. Gradually, and contesting every step, as is shown by their numerous defensive works along their path, they were forced back to their cities on this continent, that had been spared them from the universal destruction of their country, where the dense and almost impassable forests afforded them their last refuge from their enemies, and where, reduced by war, pestilence, and other causes, to a feeble band, their total extinction was only a matter of time. Such is probably the history of this lost civilization, and such would have been the history of our civilization had we in our infant growth been cut off from receiving the nourishment of the mother countries.

Within the last twenty-five years, all sciences relating to the past

and present of man have been enormously developed. Old, worn-out, useless theories have been discarded, new facts have taken their places, discoveries have followed discoveries, each discovery helping to form, link by link, the chain of human history.

We are beginning to perceive that we are but yet young in the knowledge of human history, that we have as yet picked up but a bright pebble of thought or glittering shell of theory, while before us lies the whole vast sea of human history unexplored. That we are beginning to acknowledge this is a good sign, for, when a man or mankind acknowledge their ignorance, they have at least a sure foundation to build upon.

Again, the spirit of bigotry, the spirit that told men to scorn and deride Galileo and Columbus, is fast passing away, and in its stead comes the spirit of rationality, a spirit that tells men to look upon a new idea or theory, even if it does run outside of the accustomed rut, with a reasoning if not favorable eye. And we have faith, as science grows to grander proportions and dispels some of the mist that now envelops it, that some day not far distant will bring forward an historic Edison that shall bring together the faint voice of the prehistoric past and the bright, clear voice of the present; that some future Champollion will discover, among the ruined cities of the Americas, an American Rosetta-stone that will complete the chain of human history. "The noblest study of mankind is man."

MICRO-ORGANISMS AND THEIR EFFECTS IN NATURE.

By WILLIAM S. BARNARD, Ph. D.,
PROFESSOR OF INVERTEBRATE ZOÖLOGY IN CORNELL UNIVERSITY.

WHAT is too small to be seen, people are generally apt to regard with contempt or indifference, as of no practical consequence. This is one of the grossest of popular errors. There is not only a profound scientific interest in the realm of microscopic life, which is every day becoming deeper as its organisms are viewed from the standpoint of evolution, but they have a significance in the economy of nature, a usefulness to man, and a value in the industrial arts, of which but few glimpses have as yet been popularly obtained. To the inquiry, Of what service are those swarms of infinitesimal objects which are revealed only through the microscope? do they subserve any other purpose than to amuse infatuated microscopists?—the reply is, that their operations in nature are on a grand and imposing scale, and that their influence on man and other organisms, as well as on the air, the water, and the solid earth, is nothing less than enormous.

Although we do not see these infinitesimal creatures at work, their proceedings are none the less real; and though their operations are infinitesimal, the aggregate results are vast and in the highest degree important. It may be shown—1. That, as *food*, they feed a greater number of beings than any other kind of organisms; 2. That, as *scavengers*, they eat more refuse than any other group of organisms; 3. That, despite their minuteness, their *fossil remains* are much greater in *bulk* and of far more consequence than those of large quadrupeds and serpent-like monsters, such as the *mastodon*, *megatherium*, *plesiosaurus*, *ichthyosaurus*, etc.; 4. That, as *builders*, they have produced immense structures, which far surpass in size all the colossal works of man. The evidence of these statements will be presently given; but meantime it may be remarked that such grand results redeem the study of microscopical objects from that pettiness which is often imputed to it.

But not alone because of their stupendous effects are these invisible creatures entitled to our attention. It is in the simplest and smallest creatures that we find the alphabet of the science of life. The rudimentary objects of biology are invisible; and the language of the science could never have been acquired except by first learning its A, B, C with the microscope. It is by the study of the lowest elementary forms of life that we become enabled to comprehend its higher and more complex forms, and we never could have done it otherwise. The anatomy and physiology of our own bodily structures have their roots in the invisible. The grand chain-work of relations that binds all things in order thus loses itself at one extreme in the infinitely great, and at the other in the infinitely small. Embryology, the playground of evolution, shows us microscopic embryos like adult micro-forms as necessary links in the unity of natural phenomena, so that the relationship of living things can only be comprehended by a study of the minutest objects. I do not, however, propose here to enlarge upon this aspect of the subject, but simply to offer a few illustrations of the importance of these micro-organisms.

Let us first consider the relations of microscopic animals to the crust of the earth, and notice what they have had to do with its formation and constitution. From their low grade of organization they are naturally supposed to have been the earliest creatures on our globe, and there is evidence in favor of this. In ancient geological ages, in whose rocks they are scarce, or hardly to be found at all as fossils, there lived numerous worms, mollusks, etc., which could not have subsisted without them as food. We may conclude, with some degree of certainty, that they were almost as plentiful then as now, probably more so; but we could not expect these delicate and minute objects to remain preserved until the present, to have withstood the metamorphoses of the very rocks in which they were imbedded. On this account they are exceedingly rare in the oldest formations, while the

shells of various kinds are extremely numerous in modern rocks and earth. Still, the earliest fossil known, the *Eozoön Canadense*, the organic nature of which was formerly questioned, but now seems certain, belongs to the Azoic rocks. This determination of life in what was formerly regarded as the Azoic or lifeless age, has necessitated the establishment of an age of Dawn-life, hence named Eozoic. Life in Azoic time was also inferred from its immense quantities of carbon and of graphite, the most ancient deposits of which might be of organic origin. But aside from the Eozoön fossils, we appear to have further positive evidence of life in rhizopod fossils of Stromatopore structure, as discovered in the so-called green-stones of the Huronian, as well as in the great bog-ore deposits, which were evidently formed, then as now, through the agency of swampy vegetation.

It now seems most likely that flints, called *silicic rocks*, because they contain so much of the glass-substance known as silica, were largely produced from silicic organic remains, and the correctness of this view is strongly sustained by the microscope discovering in most flinty masses the crystalline needles of sponges, incasements of diatoms, capsules of infusorians, or spheroid frames of rhizopods. The silica which percolates and hardens petrified wood and other fossils may have originated chiefly from organic structures. Also, we find in chalk the molds of the silicic parts of animals, but the silica is dissolved out and gone.

The greatest use of those animalcules which have the body of plasma incased by a cell-membrane, and are called *infusorians*, will be pointed out further on, yet their influence on the crust of our globe must be noticed here; for a few of these bear shells and hence are found in a petrified state. Their fragmentary shells almost compose the *flint* rocks at Delitzsch, near Leipsic, Saxony, while some of the living sorts occur as fossils in the coal and chalk formations. Many *green-sand rocks*, even as far down as the Silurian, consist mainly of similar silicic shells, or the nuclei or molds of their chambers. The *whetstones* so extensively manufactured from the lower green-sand stone in the Black-Down Hills of England, have probably derived their useful qualities from them. Also, the silicic *polishing-stone*, called tripoli, or Polirschiefer, in Germany, not only contains such shells, but is entirely composed of them. This substance is used chiefly as a powder for polishing metals and stones. Infusorial formations of similar character are found at Cassel, Planitz, and Bilin. The layer at Bilin, in Bohemia, is fourteen feet thick, and Ehrenberg has estimated that it contains 41,000,000,000 shells in every cubic inch, while all are united and imbedded by an amorphous silicic substance forming compact masses of rock. At Agea, in Bohemia, there is another deposit two miles long, with an average thickness of twenty-eight feet. Its upper layer is about ten feet thick, and consists wholly of such shells; while the lower eighteen feet is a dense

mixture of these with a fine granular substance. Other similar deposits appear in many parts of the world.

The many *silicic clays* owe their peculiar characters to the microscopic fossils they have contained. The *sands* and *mergel* of Sienna and Coroncina, in Italy, imbed great quantities. The lanceolets, the lowest of vertebrates, the mud-eating fishes, and the dirt-eaters among men, subsist chiefly from these tiny organisms, for the so-called "*edible earths*" and "*infusorial earths*" are made up largely of, and owe their nutritive qualities to, the remains of microscopic animals. These earths are eaten in times of need by the Lapps and Tungusians. They are likewise used in South America, in New Caledonia, Kurdistan, in China, and in some of our own Southern States. The "bread-stone" of China belongs to this kind of food. On the shores of a lake near Uranea, in Sweden, there is a large deposit of infusorial powder called *Bergmehl* (mountain-meal), which is mixed with flour and eaten. It consists almost entirely of microscopic shells.

The animalcules of plasma without a cover of cell-membrane are known as *rhizopods*, or root-footed animals. These have been of the *greatest benefit* in geological history. Those which have a central sporecase are called *radiolarians*, and generally bear beautiful spheroid, radiate, silicic frames, which have assisted largely in producing great flinty deposits in the depths of the sea, constructing extensive masses of rock. There is no doubt that they helped greatly in the formation of the silicic rocks of Virginia, the Nicobar Islands, Sicily, Barbadoes, etc. Indeed, this latter island consists almost entirely of their remains, and two hundred and thirty-two kinds have been described on it alone. Also the barren rocks, twenty feet thick, on which the city of Richmond, Virginia, stands, consist mainly oftheir discoid shells.

Other rhizopods, called *foraminifers*, produce porous, calcareous incasements for themselves and help form limestone rocks.

Surprising as it may sound, it is nevertheless true that substantially the rhizopods built the temples and mammoth pyramids of Egypt and the stone walls of Vienna and Paris, for the very rocks of these structures, as well as those which surround the Mediterranean Sea and extend thence to the Himalayan Mountains, are chiefly built up by their infinitely numerous perforated shells. There are extensive *limestone formations*, which have resulted mainly from their remains, and some of these bear their names, as the miliolithic, of the Paris basin; that of the Vienna basin; the alveolithic, of western France; and the nummulithic, of the Mediterranean. Limestones composed chiefly, sometimes entirely, of their shells, appear in the Grob-Kalk of Gentilly and in very many other localities, also forming a broad belt along both sides of the Mediterranean Sea and eastward therefrom, sometimes hundreds of feet in thickness.

But what is still more astonishing is the fact that the whole geological formation known as the *cretaceous* or *chalk* has been produced

almost entirely by their porous shells—that the immense chalk cliffs and downs along the English Channel and elsewhere have resulted from masses of their shells, and that they thus bear the same relation to the Cretaceous or Chalk as do plants to the Carboniferous or Coal age. The very dust of those chalky regions was once alive! Of course, many other kinds of organisms helped to some extent in the formation of cretaceous deposits, but the great bulk was undoubtedly of rhizopod origin. Standing at Dieppe, France, beneath the immense chalk cliffs of the English Channel, one can hardly realize that these beds of solid chalk, hundreds of feet in thickness, are the produce of such diminutive beings. But when we reflect that the chalk is five hundred and thirty-five feet high at Beachy Head, and five hundred feet at Wendover Hill, that it has been bored into five hundred and ten feet at Diss, in Norfolk, and that its average thickness has been estimated by reliable geologists, such as De la Bêche and others, at about seven hundred feet, while it extends through all the northern part of France as far south as Aix-la-Chapelle, thence northward to Denmark and through the south part of England to the Isle of Wight; and that its outcroppings have been traced from the north of Ireland to the south of France and eastward to the borders of Asia Minor, while a belt of cretaceous deposits extends around the earth just north of the equator, and numerous other chalk regions occur, like that reaching from Terra del Fuego to New Granada, in South America, besides those in our own country—very extensive in the Western, less so in the Southern States—we begin to perceive in what overwhelming quantities these organisms have existed, and what a stupendous work they have performed. The microscopic animals of the Cretaceous may be individually insignificant, but *en masse* they are certainly far more important than such larger fossils as the *mosasaurus*, *pterodactylus*, *iguanodon*, *ichthyosaurus*, and species of large fossil turtles of the same age, or the elephant-like mastodons and ponderous, sloth-like megatheriums of more modern date. The microscopic shells, which chalk contains, are mostly in a fragmentary condition, yet plenty are entire enough to be readily identified, and the number of different kinds (species) involved was very great, for about three hundred species have been described. Twenty of these species are *still living* and more or less actively engaged, along with other living species, in the construction of *modern* chalk, or the chalk-mud of the Atlantic basin. Here in the bottom of the sea we have chalk in the actual process of formation to-day. It was long since said by Dr. Mantell that "chalk forms such an assemblage of sedimentary deposits as would probably be presented to observation if a mass of the bed of the Atlantic two thousand feet in thickness were elevated above the waters and became dry land; the only essential difference would be the generic and specific characters of the imbedded animal and vegetable remains," * and

* "Wonders of Geology," 1848, vol. vi., p. 305.

this view has lately been substantiated by the deep-sea investigations of English naturalists. Wyville Thomson says: "There can be no doubt whatever that we have forming at the bottom of the present ocean a vast sheet of rock which very closely resembles chalk; and there can be as little doubt that the old chalk, the Cretaceous formation, which in some parts of England has been subjected to enormous denudation, and which is overlaid by the beds of the Tertiary series, was produced in the same manner and under closely similar circumstances"; and he also thinks it is "probable that in the deeper parts of the Atlantic a deposit, differing possibly from time to time in composition, but always of the same general character, might have been accumulating continuously from the Cretaceous, or even earlier periods, to the present day."* What enormous swarms and successive generations of rhizopods have existed, to effect such amazing results! Were all the extinct chalk animals resurrected at once, they would envelop the earth as did the primitive waters before the land was apart from the sea; we should have an ocean of protoplasm filled with their shells. Figuier truly says: "With these microscopic animals Nature has worked wonders in geological times; nor have those wonders ceased in our days."

Their diminutive size, marvelous reproductive capacity, and tenacity of life, together with the readiness with which they adapt themselves to new and various conditions of existence, not only have insured them a wide *distribution* in space, but also have enabled them to survive the destructive causes which exterminated higher forms through long and successive ages of geological time. Among about one hundred and twenty-five kinds (genera) of shelled, root-footed animals, only about fifteen are not fossil. Of the one hundred and ten species of those with perforated shells now living in the Atlantic chalk-ooze, the number of species common to it and the various geological formations in England is estimated as fifty-three with the crag, twenty-eight with the London clay, nineteen with the chalk, seven with the Rhætic and Upper Trias, one with the Permian, and one with the Carboniferous. The survival of so many species in the group is a striking testimony against the theory that the species of each geological division of time ended in a totally demolishing and exterminating catastrophe. The links in their chain are small but numerous, continuously uniting the organic life of remote ages with that of to-day.

At present the immense numbers of their shells on some shores is remarkable; indeed, the sands of some localities are largely composed of them. D'Orbigny obtained 3,800,000 porous shells from a single ounce of sand on the shores of the Antilles. According to Soldani, one ounce of sand from Rimini, on the Adriatic, yields 6,000 shells. This scientist described and figured a great number of these in Italy, publishing an elaborate folio work with 228 copperplate illustrations,

* "Depths of the Sea," p. 470.

and then destroyed the whole edition a few days afterward, because he could find only six purchasers of the work, to the preparation of which he had devoted twenty years of his life! These organisms were as poorly appreciated then as now. Max Shultze reports that he has separated 1,500,000 specimens from one ounce of sifted sand from the coasts of Italy, near Mola di Gaeta. Also the deep-sea sands are in great part made up of their shells. In most of these the perforated forms abound, but in many localities the silicic symmetrical frames are most numerous. Until recently the great depths of the ocean were supposed to be dark, barren wastes; that the lack of oxygen, with the immense pressure of water from above, rendered these abysses impenetrable and uninhabitable. But the success of modern deep-sea soundings, particularly in the region of the Atlantic cable, has shown that the Atlantic ooze or chalk-mud, of which the ocean-bed is so largely composed, is literally alive with protoplasmic animalcules, whose innumerable shells and calcareous deposits give to this ooze its peculiar character, and are virtually constructing beds of chalk. These and other facts have led some of our best authorities to believe that the formation of chalk has been a continuous process from the Cretaceous time to the present.

In their geographical distribution most have an extremely wide range, and great numbers of species are cosmopolitan in their occurrence, yet there is a general uniformity of the conditions under which they exist. For example, *globigerina* appears often in such great depths of the ocean that the temperature of its habitat hardly varies with the seasons, or even for different zones, while the same species under different conditions of depth, temperature, etc., does show very strong varieties, which are sometimes so markedly distinct as to be accounted different species and genera, as has often been asserted by Carpenter, Williamson, and others. Professor Carpenter also states that Messrs. Parker and Jones became so familiar with the geographical variations of the species of perforated shells, that they could judge from the appearance of a specimen whence it came.

The *infusorians* belong chiefly to the fresh water, being plentiful in all lakes, ponds, swamps, rivers, and smaller streams, while only a few are marine; contrariwise, the rhizopods are mostly found in the seas, a small number inhabiting fresh waters. The rhizopods also serve an important function in the depths of the sea by setting free in the water large supplies of carbonic and phosphoric acids. Certain infusorian lash-swimmers (*noctiluca*, etc.) sometimes make the ocean look red or bloody by day and illumine it with phosphorescence at night. This is often observed in the Red Sea, in the Gulf of Guinea, off the north of France, on the Peruvian coasts, and in the Gulf of California, which on this account was called Mar Vermijo, or Vermilion Sea, by the early Spanish navigators.

With few exceptions, microscopic beings possess the power of

moving from place to place, although many enjoy this freedom for only a part of their lifetime, and then become adherent or attached to foreign bodies for the rest of their existence. But even with the most rapid, free swimming forms, so little distance can be accomplished in their almost momentary lives, that their voluntary progressions can have little or no effect on their geographical distribution. In this they are creatures of chance or circumstance. Multiplying in myriads, and being too small and weak to resist the elements, they are constantly swept about in currents of water or air, and in the moisture on the surfaces of moving animals, etc. Well-authenticated observations show that with the evaporation of ponds and other waters containing swarms of these little animals, many encyst themselves within delicate capsules formed of an exudation, which hardens the body-surface; they then dry up and become as particles of dust, which are wafted from place to place by the winds, and for weeks or months may lie in the mud, dust, or snow, on hay, moss, branches of trees, etc. Others decompose, but leave behind their germs, which are distributed in the same way. By these means they are scattered everywhere, and those which chance to fall into favorable situations survive and produce swarms of progeny, while others, falling on bad ground, perish. Thus they are ready to do their appointed work, whenever and wherever it is needed. It is commonly thought that pure drinking-water is filled with these microscopic creatures, and it is sometimes said that they constitute the life of the water, while in their absence it becomes dead, stagnant, and often slimy, green, and unfit for use. All this is the opposite of the facts. Pure water is not inhabited by organisms; on the contrary, stagnant water or impure water alone affords them subsistence. They hasten the destruction of dead animal and vegetable matters the water may contain, causing for the time being an infusion or fermentation, which results finally in the purification of the liquid in question.

The bodily corruption in diseases, whether contagious or not, is not caused alone by the swarms of infesting organisms associated therewith, but is simply their cause, a sustenance for them, itself making their existence and multiplication possible.

The unaccounted-for readiness of these animalcules to spring up wherever decaying organic matter existed, first suggested the name *infusoria*, and led to the early false opinions that they were generated by the decomposition and fermentation of organic bodies, and to the modern reformed theory of *spontaneous generation*.

Strangely seeming, yet true, stagnation, death, decay, are replete with life when viewed through lenses, so that it has become a scientific doctrine that all organic decomposition and fermentation is assisted and sustained by these tiny creatures. Hence we may regard them as the most important scavengers of earth, water, and air.

While their devouring work is as a "bottling up" of injurious and

infectious matters, thus purifying our world, the substances their little bodies may contain and their parasitic action when inoculated into the bodies of higher living organisms by contact, inhalation, eating, etc., render some kinds extremely dangerous as conveyers of the various contagious diseases, hence to be strenuously avoided by strict cleanliness and rigid hygienic measures of every kind. Such knowledge has done much toward inducing modern purity, and has led to our recently improved treatment of wounds and sores by the antiseptic method, whereby many benefits result and great numbers of lives are saved.

THE SCIENCE AND PHILOSOPHY OF RECREATION.*

By GEORGE J. ROMANES.

IN all places of the civilized world, and in all classes of the civilized community, the struggle for existence is now more keen than ever it has been during the history of our race. Everywhere men, and women, and children are living at a pressure positively frightful to contemplate. Amid the swarming bustle of our smoke-smothered towns, surrounded by their zone of poisoned trees, amid the whirling roar of machinery, the scorching blast of furnaces, and in the tallow-lighted blackness of our mines—everywhere, over all the length and breadth of this teeming land, men, and women, and children, in no metaphor, but in cruel truth, are struggling for life. Even our smiling landscapes support as the sons of their soil a new generation, to whom the freedom of gladness is a tradition of the past, and on whose brows is stamped, not only the print of honest work, but a new and sadding mark—the brand of sickening care. Or if we look to our universities and schools, to our professional men and men of business, we see this same fierce battle rage—ruined health and shattered hopes, tearful lives and early deaths being everywhere the bitter lot of millions who toil, and strive, and love, and bleed their young hearts' blood in sorrow. In such a world and at such a time, when more truly than ever it may be said that the whole creation groans in pain and travail, I do not know that for the purposes of health and happiness there is any subject which it is more desirable that persons of all classes should understand than the philosophical theory and the rational practice of recreation. For recreation is the great relief from the pressure of life—the breathing-space in the daily struggle for existence, without which no one of the combatants could long survive; and therefore it becomes of the first importance that the science and the philosophy of such relief should be generally known. No doubt it is true that people will

* Expanded from notes of a Lecture delivered before the National Health Society.

always be compelled to take recreation and to profit by its use, whether or not they are acquainted with its science and its philosophy; but there can be equally little doubt that here, as elsewhere, an intelligent understanding of abstract principles as well as of practical applications will insure more use and less abuse of the thing which is thus intelligently understood.

With a view, then, of obtaining some such intelligent understanding of recreation, let us begin by clearly understanding what recreation means. First of all, the mere word, like many of our other English words that signify abstractions, condenses much philosophy within itself. For, as "creation" means a forming, "re-creation" means a forming anew; and, as in etymological derivation, so in actual truth re-creation is nothing other than a re-novation of the vital energies; leisure time and appropriate employment serve to repair the organic machinery which has been impaired by the excess of work. The literal meaning of the word is therefore in itself instructive, as showing that what our forefathers saw in recreation was not so much play, pastime, or pleasantry, as the restoration of enfeebled powers of work. And I do not know that within the limits of one word they could have left us a legacy of thought more true in itself or more solemn in its admonition. Recreation is, *or ought to be*, not a pastime entered upon for the sake of the pleasure which it affords, but an act of duty undertaken for the sake of the subsequent power which it generates, and the subsequent profit which it insures. Therefore, expanding the philosophy which is thus condensed in our English word, we may define recreation as that which with the least expenditure of time renders the exhausted energies most fitted to resume their work. Such is my definition of recreation; yet I know that many things are called by this name which can not possibly fall within this definition, and I doubt whether nine persons out of ten ever dreamed either of attaching such a meaning to the word, or of applying such a principle to the thing. Nevertheless, I also know that in whatever degree so-called recreation fails to be covered by this definition, in that degree does it fail, properly speaking, to be recreation at all. It may be amusement, fun, or even profitable employment; but it is not that particular thing which it is the object of this paper to consider. Therefore the definition which I have laid down may be taken as a practical test of recreation as genuine or spurious. If recreation is of a kind that renders a man less fitted for work than would some other kind of occupation, or if it consumes more time than would some other kind of occupation which would secure an equal amount of recuperation, then, in whatever degree this is so, in that degree must the quality of such recreation be pronounced impure.

So much, then, for the meaning of recreation. The next point that I shall consider is the physiology of recreation. It may have struck some readers as a curious question, why some actions or pur-

suits should present what I may call a recreative character, and others not. For it is evident that this character is by no means determined by the relief from *labor* which these actions or pursuits secure. A week on the moors involves more genuine hard work than does a week in the mines, and a game of chess may require as much effort of thought as a problem in high mathematics. Moreover, the same action or pursuit may vary in its recreative quality with different individuals. Rowing, which is the favorite recreation of the undergraduate, is serious work to the bargeman; and we never find a gardener to resemble his master in showing a partiality to digging for digging's sake. If it is suggested that it is the need of bodily exercise which renders muscular activity beneficial to the one class and not to the other, I answer, no doubt it is so partly, but not wholly; for why is it that a man of science should find recreation in reading history, while an historian finds recreation in the pursuit of science? or why is it that a London tradesman should find a beneficial holiday in the country, while a country tradesman finds a no less beneficial holiday in London? The truth seems to me to be that the only principle which will serve to explain the recreative quality in all cases is what I may call the physiological necessity for frequent change of organic activity, and the consequent physiological value of variety in the kinds and seasons of such activity. In order to render this principle perfectly clear, it will be necessary for me very briefly to explain the physiology of nutrition.

When food is taken into the body it undergoes a variety of processes which are collectively called digestion and assimilation. Into the details of these processes I need not enter, it being enough for my present purpose to say that the total result of these processes is to strain off the nutritious constituents of the food, and pour them into the current of the blood. The blood circulates through nearly all the tissues of the body, being contained in a closed system of tubes. This system of tubes springs from the heart in the form of large, hollow trunks which ramify into smaller and smaller tube-branches. These are all called arteries. The smaller arteries again ramify into a countless meshwork of so-called capillaries. Capillaries are also closed tubes, but differ from arteries in being immensely more numerous, more slender, and more tenuous in their walls. These capillaries pervade the body in such an intimate meshwork that a needle's point can not be run into any part of the body where they occur without destroying the integrity of some of them, and so causing an outflow of blood.

As these capillaries ramify from the arteries, so do they again coalesce into larger tubes, and these into larger, and so on, until all this system of return tubing ends again in the heart in the form of large, hollow trunks. The tubes composing this system of return tubing are called the veins. Thus the whole blood-vascular system may be likened to two trees which are throughout joined together by their leaves, and

also by cavities at the bottoms of their trunks—the heart. The branches of both trees being everywhere hollow, the contained fluid runs up the stem, and through smaller and smaller branches of the arterial tree, into the delicate vessels of the leaves, which may be taken to represent the capillaries. Passing through these into the twigs of the venous tree, the blood returns through larger and larger branches of this tree till it arrives at the trunk, and completes its circuit by again entering the trunk of the arterial tree through the cavities of the heart. Now the blood, in perpetually making this complete circuit of the body, performs three important functions: it serves to carry oxygen from the lungs to all the other parts of the body; it serves to supply all parts of the body with the nutritive material with which it is charged; and it serves to drain off from all the tissues of the body the effete products which they excrete, and to present these effete products to the organs whose function it is again to abstract them from the blood and expel them from the body. The two latter functions of the blood —those of nourishing and draining—I must consider more in detail. They are both performed in the capillaries, so that the object of the arteries and veins may be considered as merely that of conveying the blood to and from the capillaries. Moreover, both functions are performed by transfusion through the delicate walls of the capillaries—the nutritive material in the blood being thus transfused into the surrounding tissues, and the waste product of these tissues being transfused into the blood. Thus, in the various vascular tissues there is always a double process going on: first, that of receiving nourishment from the blood, whereby they are being constantly built up into an efficient state for the performance of their various functions; and, secondly, that of discharging into the blood the effete materials which the performance of these functions entails. Now, when any tissue or organ is in a state of activity in the performance of its function, the activity which it manifests entails a process of disintegration, which is the reverse of the process of nutrition; that is to say, when a tissue or organ is doing its work, it is expending energy which it has previously derived in virtue of the process of nutrition. Work is therefore, so to speak, the using up of nutrition; so that if the income of energy due to nutrition is equal to the expenditure of energy due to work, the tissue or organ will remain stationary as regards its capacity for further work, while, if the work done is in excess of the nutrition supplied, the tissue or organ will soon be unable to continue its work; it will become, as we say, exhausted, cease to work, and remain passive until it is again slowly and gradually refreshed or built up by the process of nutrition. Therefore all the tissues and organs of the body require periods of rest to alternate with periods of activity; and what is true of each part of the body is likewise true of the body as a whole—sleep being nothing other than a time of general rest during which the process of nutrition is allowed to gain upon that of exhaustion. Thus we

may have local exhaustion—as when the muscles of our arm are no longer able to hold out a heavy weight—or we may have general exhaustion, as in sleep; and we may have local restorations due to nutrition—as when our exhausted arm, after some interval of rest, is again able to sustain the weight—or we may have a general restoration due to nutrition, as in the effects of sleep.

I have now said enough about the physiology of nutrition to render quite clear what I mean by recreation depending on the physiological necessity for a frequent change of organic activity. For although in the case of some organs—such as most of the secreting organs—activity is pretty constant, owing to the constant expenditure of energy being just about balanced by the constant income, in the case of nerves and muscles this is not so; during the times when these organs are in activity their expenditure of energy is so vastly greater than their income during the same times, that they can only do their work by drawing upon the stores of energy which have been laid up by them during the comparatively long periods of their previous rest. Now, recreation applies only to nerve and muscle; and what it amounts to is simply this—a change of organic activity, having for its object the affording of time for the nutrition of exhausted portions of the body. A part of the body having become exhausted by work done, and yet the whole of the body not being exhausted so far as to require sleep, recreation is the affording of local sleep to the exhausted part by transferring the scene of activity from it to some other part. Be it observed that a certain amount of activity is necessary for the life and health of all the organs of the body; so it would not do for the community of organs as a whole that, when any one set become exhausted by their own activity, all the others should share in their time of rest, as in general sleep. But, by transferring the state of activity from organs already exhausted by work to organs which are ready nourished to perform work, recreation may be termed, as I have said, local sleep.

Thus we see that, in a physiological no less than in a psychological sense, the term re-creation is a singularly happy one; for we see that, as a matter of fact, the whole physiology of recreation consists merely of a re-building up, re-forming, or re-creation of tissues which have become partly broken down by the exhausting effects of work. So that in this physiological sense recreation is partial sleep, while sleep is universal recreation. And now we see why it is that the one essential principle of all recreation must be that of variety of organic activity; for variety of organic activity merely means the substitution of one set of organic activities for another, and consequently the successive affording of rest to bodily structures as they are successively exhausted. The undergraduate finds recreation in rowing because it gives his brain time to recover its exhausted energies, while the historian and the man of science find recreation in each other's labors

because these labors require somewhat different faculties of mind for their pursuance.

Before concluding these general remarks on the physiology of recreation, I must say a few words with more special reference to the physiology of exercise. We do not require science to teach us that the most lucrative form of recreation for those whose labor is not of a bodily kind is muscular exercise. Why this should be so is sufficiently obvious. The movement of blood in the veins is due to two causes.

The act of drawing breath into the lungs, by dilating the closed cavity of the chest, serves also to draw venous blood into the heart. This cause of the onward movement of blood in the veins is what is called aspiration, and it occurs also in some of the larger veins of the limbs, which are so situated with reference to their supplying branches that movement of the limbs determines suction of the blood from the supplying branches to the veins. The second great cause of the venous flow is as follows: The larger veins are nearly all provided with valves which open to allow the blood to pass on toward the heart, but close against the blood if it endeavors to return back toward the capillaries. Now, the larger veins are imbedded in muscles, so that the effect of muscular contractions is to compress numberless veins now in one part and now in another part of their length; and, as each vein is thus compressed, its contained fluid is, of course, driven forward from valve to valve. Hence, as all the veins of the body end in the heart, the total effect of general muscular activity is greatly to increase the flow of venous blood into the heart. The heart is thus stimulated to greater activity in order to avoid being gorged with the unusual inflow of blood. So great is the increase of the heart's activity that is required to meet this sudden demand on its powers of propulsion, that every one can feel in his own person how greatly muscular exercise increases the number of the heart's contractions. Now, the result of this increase of the heart's activity is, of course, to pump a correspondingly greater amount of blood into the arteries, and so to quicken the circulation all over the body. This, in turn, gives rise to a greater amount of tissue-change—oxygenation, nutrition, and drainage—which, together with the increased discharge of carbonic acid by the muscles during their time of increased activity, has the effect of unduly charging the blood with carbonic acid and other effete materials. This increased amount of carbonic acid in the blood stimulates the respiratory center in the spinal cord to increase the frequency of the respiratory movements, so that under the influence of violent and sustained exercise we become, as it is expressively said, "out of breath." The distress to which this condition may give rise is, however, chiefly due to the heart being unable to deliver blood into the arteries as quickly as it receives blood from the veins; the result being a more or less undue pressure of venous blood upon a heart already struggling to its utmost to pump on all the blood it can. Training, which is

chiefly systematic exercise, by promoting a healthy concordant action between the heart and arteries, diminishes the resistance which the latter offer to an unusual flow of blood from the former, and therefore men in training, or men accustomed to bodily exercise, do not easily become distressed by sustained muscular exertion.

Now it is evident, without comment, how immense must be the benefit of muscular exercise. Not only does it allow time for the brain to rest when exhausted by mental work, but, by increasing the circulation all over the body, it promotes the threefold function of oxygenation, nutrition, and drainage. It thus refreshes the whole organism in all its parts; it increases by use the strength and endurance of the muscles; it maintains the heart and the lungs—or rather the whole of the circulatory and respiratory mechanisms—at the highest point of their natural efficiency; and, in general, next only to air and food, muscular exercise is of all things most essential to the vitality of the organism.

So much, then, for the physiology of recreation; and, having said this much on the abstract principles of our subject, I shall devote the rest of my paper to a consideration of this subject in its more practical aspects.

The fundamental principle of all recreation consisting, as I have said, in the rest from local exhaustion which is secured by a change of organic activity, it is clear that practical advice with regard to recreation must differ widely according to the class, and even the individual, to which it is given. Thus it would be clearly absurd to recommend a literary man, already jaded with mental work, to adopt as his means of recreation some sedentary form of amusement; while it would be no less absurd to recommend a workingman, already fatigued with bodily toil, to regale himself with athletics. And, in lower degrees, the kind and amount of recreation which it would be wise to recommend must differ with different individuals in the same class of society, according to their age, sex, temperament, pursuits, and previous habits of life. But, although all matters of detail thus require to be adjusted to individual cases, there is one practical consideration which applies equally to all cases, and which must never be lost sight of if recreation of any kind is to produce its full measure of result. This consideration is the all-important part which is played in recreation by the emotions. It is, I am sure, impossible to over-estimate the value of the emotions in this connection—a prolonged flow of happy feelings doing more to brace up the system for work than any other influence operating for a similar length of time. The physiological reasons why this should be so are not apparent; for, although we know that the emotions have a very powerful influence in stimulating the nerves which act on the various secreting organs of the body, I do not think that this fact alone is sufficient to explain the high value of pleasurable emotions in refreshing the nervous system. There

must be some further reason—probably to be sought for within the limits of the nervous system itself—why a flow of happy feelings serves to re-create the nervous energies. But, be the reasons what they may, we must never neglect to remember the fact that the influence of all others most detrimental to recreation is the absence of agreeable emotions or the presence of painful ones. There is, for instance, comparatively little use in taking so-called constitutional exercise at stated times, if the mind during these times is emotionally colorless, or, still worse, aching with sorrow and care. If recreation is to be of good quality, it must before all things be of a kind to stimulate pleasurable feelings, and while it lasts it ought to engross the whole of our consciousness. Half-hearted action is quite as little remunerative here as elsewhere; and, if we desire to work well, no less in play than in work must we fulfill the saying, "What thy hand findeth to do, do it with thy might."

Having stated this practical principle as of paramount importance in all recreation, I shall devote the rest of my space to giving a variety of suggestions concerning the recreation of all classes of society; and, for the sake of securing method to my discussion, I shall primarily consider the community in its most natural classes of men, women, and children.

There is not much to be said on the recreation of men belonging to the upper classes. That most objectionable of creatures, the gentleman at large without occupation, has a free choice before him of every amusement that the world has to give; but one thing he is hopelessly denied—the keen enjoyment of recreation. Living from year to year in a round of varied pastimes, he becomes slowly incapacitated for forming habits of work, while at the same time he is slowly sapping all the enjoyment from play. For, although variety of amusement may please for a time, it is notorious that it can not do so indefinitely. The intellectual changes which are involved in changes of amusement are not sufficiently pronounced to re-create even the faculties on which the sense of amusement depends; the mind, therefore, becomes surfeited with amusement of all kinds, just as it may become surfeited with a tune too constantly played—even though the tune be played in frequently changing keys. For such men, if past middle life, I have no advice to give. They have placed themselves beyond the possibility of finding recreation, and their only use in the world is to show the doom of idleness. They, more even than paupers, are the parasites of the social organism; and we can scarcely regret that their lumpish life, being one of stagnation self-induced, should be one of miserable failure, to the wretchedness of which we can extend no hope.

Turning next to gentlemen of active pursuits, I may most fitly begin with those who are beginning life at the universities. At our larger universities both the provisions for recreation and the manner

in which they are used are in a high degree satisfactory, and ought to serve as a model to universities all over the world. It may be true that at the Continental universities rowing would not inspire a tenth part of the enthusiasm which it creates at Oxford and Cambridge; and I know from experience that it is hopeless to persuade German students, as a class, to adopt what they consider childish toys—the bats and balls of cricket. All I can say is, so much the worse for the Continental universities. In everything that appertains to work—and more especially to original work—I am profoundly convinced that the sooner we copy something from the German universities the better; but, in most things that appertain to play, the English universities constitute the best models. Rowing, cricket, football, athletics, and, in a lower degree, gymnastics, bicycling, swimming, and riding, constitute, besides walking, the favorite modes of exercise; and it is impossible to suggest better. I have only to object that, regarded as recreation, there is, both at Oxford and Cambridge, far too much tendency to a specialization of these forms of exercise. Competition dictates practice, and practice entails too exclusive a devotion to the one kind of exercise which is practiced; so that, as a consequence, there is too sharp a division between the boating-men, the cricketers, and the athletes for securing the full benefit of exercise which all would derive if they were more usually to participate in one another's pursuits. But this evil is to some extent unavoidable, as it arises immediately from the spirit of emulation, without which the mere exercise would lose its zest, and so the fullness of its recreative value. Still, now that so many of the colleges are provided with their own cricket-grounds, and the boats are practically open to all, there is no reason why even the most ambitious aspirants to the "'varsity blue" should not enjoy more variety of exercise than is usually the case.

In the army and navy there is abundant time for recreation, which is too frequently wasted in mere lounging. When once the army or navy examinations are passed, there is comparatively little mental work required in the performance of duty, and therefore the comparatively large amount of leisure time which officers enjoy ought to be much more generally devoted than it is to reading, or even to original work. Officers constitute a class presenting no small proportion of intelligent members; so that the comparative rareness with which they present either high culture or proved powers of original work must, I think, be set down to a general bad habit or fashion of substituting idle amusement for profitable recreation.

To professional men, men of business, and indeed all who are engaged in pursuits requiring more or less severe mental work, coupled with more or less confinement, exercise is, of course, the *conditio sine qua non* of the recreation to be recommended. This fact is so obvious that I need not dwell upon it further than to make one remark. This is to warn all such persons that their feelings are no safe guide as to

the amount of muscular exercise that is requisite for maintaining full and *sustained* health. By habitual neglect of sufficient exercise the system may and does accommodate itself to such neglect; so that not only may the desire for exercise cease to be a fair measure of its need, but positive exhaustion may attend a much less amount of exercise than is necessary to long continuance of sound health. However strong and well, therefore, a man may feel notwithstanding his neglect of exercise, he ought to remember that he is playing a most dangerous game, and that sooner or later his sin will find him out—either in the form of dyspepsia, liver, kidney, or other disease, which so surely creep upon the offender against Nature's laws of health. According to Dr. Parkes, the amount of exercise that a healthy man ought to take without fatigue is at the least that which is required for raising 150 foot-tons per diem. This, in mere walking, would, in the case of a man of ordinary weight, be represented by a walk of between eight and nine miles along level ground, or one mile up a tolerably steep hill; but it is desirable that the requisite amount of exercise should be obtained without throwing all the work upon one set of muscles. For this reason walking ought to be varied with rowing, riding, active games, and, where practicable, hunting or shooting, which, to those who are fond of sport, constitute the most perfect form of recreative exercise.

Turning next to all the large class of men below the grade of clerks, their possible means of recreation are alike in this—that they must be more or less of a corporate kind. These men depend for their recreation on public institutions, and therefore it is of the first importance to the national health, happiness, morals, and intelligence that no thought, pains, or money should be spared in providing such institutions, adequate in number and competent in character to meet so important and so immense a need. Within the limits of so general an essay it is impossible to do anything like justice to this subject; but I may say a few words on the kinds of institutions that I should most like to recommend.

Every town the size of which is so considerable that green grass and fresh air are not within easy reach of all its inhabitants, ought at any expense to be provided with public parks. In many of our large towns it is now virtually impracticable to provide such parks in central situations; but even suburban parks are infinitely better than no parks at all. Public recreation-grounds having been provided, every inducement ought to be added to attract the people to use them. Gymnasia, boating, cricket and golf implements, lawn-tennis, and tennis-courts, ought all to be supplied at the public expense, so that workingmen and boys might be able to spend their holidays and half-holidays in healthy outdoor amusement without requiring to incur the expense of club subscriptions. Outdoor clubs, however, ought not the less to be encouraged for the sake of the additional inducement which *esprit de*

corps and competition give to outdoor recreation—the club subscriptions being limited to the providing of prizes. Bands ought also to be provided at the public expense to play in the parks during the spring and summer months on the afternoons of holidays and Sundays. The importance of this latter provision can not be too highly rated; for experience shows that wherever it has been tried its success has been astonishing. For instance, Lord Thurlow, quoting from Sir Benjamin Hall, stated to the House of Lords, on the 5th of May, that the Sunday visitors to Kensington Gardens had, by the band playing there, been increased from 7,000 to 80,000 in one day, and in the Regent's and Victoria Parks 190,000 had been attracted by the bands in one afternoon. When we consider what an amount of health, happiness, and refining influence these numbers represent as produced by a single cause, we blush for the narrow fanaticism which, in the name of religion, does all it can to deny to the working-classes the elevating influence of music on the only day that the toil of life admits of their obtaining it. I hold it to be impossible too strongly to deprecate the downright immorality of driving the working-classes by thousands into the pot-houses by depriving them of the innocent and refining enjoyment of music in the open air. Surely the common sense of the public, as a whole, is not so degraded by bigotry that, in the face of the figures I have quoted, there can any longer be a question in the public mind on the positive sin of allowing a puritanical spirit in the few to domineer over the health, the happiness, and the morals of the many.

Somewhat similar remarks apply to the question of opening museums and art-galleries on Sundays, though on this question the sabbatarians include among their ranks a greater proportional number of the community. In the debate of the 5th of May, to which I have already alluded, both Church and State, in so far as they are represented in the persons of the Primate and the Premier, spoke strongly against any reform in this direction; and, perhaps owing to this weight of united authority, the proposed reform was negatived by a majority of eight. Yet, when we examine the arguments which these high authorities were able to produce, we find them to be conspicuously of the feeblest kind. The leading argument both of the Prime Minister and of the Archbishop was that there is not sufficient evidence "of a very predominant sentiment" in favor of the reform on the part of workingmen themselves. Now, to this it may be answered, in the first place, that a poll on the question has not been taken, and that, therefore, it is a mere begging of the question to say that workingmen as a class "in all probability" do not desire the change. But, even if we grant that the working-classes as a whole are as apathetic upon the subject as they are represented to be, I do not see that this is any valid reason against reform. Possibly enough, the members of the House of Lords have a higher appreciation of the value of science-museums

and art-galleries, as well as the privileges and advantages of entering them, than have the members of workingmen's clubs; and I doubt not that, if the upper and the lower classes were for a few months to change places, petitions to Parliament of the kind which Lord Thurlow presented would be more numerous and more generally signed. But what does this argue? Surely not that we, who best know the culturing value of these institutions, ought to use the comparative ignorance of those who do not as an argument against extending to them the opportunity of ascertaining that value. On the contrary, in whatever degree indifference can be proved of the working-classes in this matter, it would seem to me a strong argument in favor of instilling into them a more lively perception of the educational advantages of such institutions; and this can only be done by throwing open these institutions on the (virtually) one day in the week when the classes in question are able to visit them. Of course, it may be said that the alleged indifference arises, not from ignorance of the value of such institutions, but from a preponderant sense of sabbatarianism on the part of the working-classes. But, supposing the alleged apathy to exist, and supposing it to arise from the latter cause alone—which I deem highly improbable—I still think it would constitute no valid argument against the proposed reform. We are all, I take it, agreed upon the recreative as well as what Lord Beaconsfield called the civilizing influence of the institutions in question; so that, upon the suppositions which I have made, the only issue to be considered is as to whether these benefits would be more than counterbalanced by the evils of offending the sense of sabbatarianism which is assumed so largely to predominate among the working-classes. And this introduces us to the second and only other argument which was adduced by Lord Beaconsfield. He said: "In all questions into which the religious sentiment enters, it is highly desirable that no change should be effected that is not called for by the expression of a very predominant sentiment on the part of the people." If this means that legislation ought not to interfere aggressively with the religious sentiments of the many, it is, no doubt, a proper utterance; but, if it means that the socially harmless and even beneficial recreation of the many is to be prohibited by the particular religious sentiments of the few—and this is what it does mean if the words are taken to mean what they say—then I think the utterance is most improper. The idea which underlies this utterance seems to be that the religious sentiment is of so much value to the state that it ought to be tenderly fostered in all its ramifications, even to the extent of preventing reforms conceded to be beneficial, lest they should prune the twigs of the structure thus tenderly fostered. Now, I do not wish to enter on the question as to how far the religious sentiment is of value to the state; for I think it is quite obvious in the present case that, let us place this value as high as we choose, the contemplated reform can not be other than complete-

ly beneficial. The workingmen who prefer spending their Sundays at home would not be injured by their brothers visiting museums and art-galleries; while, in so far as the religious sentiment is concerned, it ought to be a matter of gratification to all who entertain it that those workingmen who do not prefer spending their Sundays at home would, by the opening of such institutions, have an inducement supplied to turn their backs upon the beer-shops, and to bring their families to see the things of interest in nature, or the things of beauty in art. It is not that the opening of the institutions in question would act as a counter-inducement to that which is held out by the churches. Workingmen who are in the habit of going to church will, in any case, continue going to church, even though some of them may also spend their Sunday afternoons in the museums and galleries. And, so far as recreation is concerned, I am inclined to think it is not desirable that there should be any antagonism offered to the inducement which is held out by the churches. For I am inclined to think that the class of emotions which public worship arouses in a religious mind are of a high recreative value; and so, as a mere matter of sanitary interest, I should be sorry to see the churches interfered with by other institutions of a less recreative kind. But, in the present instance, the antagonism should not be museums and galleries *versus* chapels and churches, but museums and galleries *versus* public-houses and all places of loitering idleness; and any "religious sentiment" that seeks to oppose the introduction of such an antagonism can only be pronounced immoral.

Two other arguments against the reform were adduced in the debate, neither of which possesses the smallest validity. The Archbishop of Canterbury argued: "What were their lordships called upon to do to-night? It was before the eyes of the people of this kingdom, to pronounce a deliberate opinion that the policy with regard to the observance of the Sunday hitherto pursued in this country had been a mistake. . . . If any change were made, there was great danger of the day of rest being lost," as it would be the thin edge of the wedge to the introduction of other changes of a more advanced kind. Now, this is an argument which may always be adduced against any proposed reform, however obvious the need. We must not make the change because by so doing we should condemn the policy of the past and lead the way to further changes in the future. But, if a change is seen in itself to be desirable, such hypertrophied conservatism as this ought not to be allowed to obstruct progress. Moreover, in the present instance I am persuaded that the fears for the future are groundless. There is no necessary, or even remote, connection between art-galleries and music-halls; and, so long as "the religious sentiments" in this country remain what they are, neither religion nor reason will be able to trace a similarity or a precedent that does not exist.

The other argument to which I have alluded is, that the opening of museums and galleries on Sundays would entail a certain amount of

Sunday work on the part of porters, etc. To this argument it is sufficient to reply, in the first place, that, if desirable, voluntary labor of so light a kind would be forthcoming; and, next, in the words of the Earl of Derby, who "did not deny the extreme importance of maintaining the day of national rest; but they must recollect that, wherever recreation was allowed, some labor must be thrown on those who provided it. They permitted excursion-trains, etc., . . . and on the whole there was a great preponderance of advantage over disadvantage." As in most museums and galleries the porters and other servants employed on Sundays would probably not amount to one half per cent. of the visitors who would profit by their labor, I think that the argument may in this, more than in any other case of Sunday work, be set aside as absurd.

I have been tempted to dwell thus at considerable length on the question of Sunday recreation, because it is one that is now prominently before the public, and therefore I hope that a few words in season may help to hasten a reform which sooner or later is inevitable. As regards the recreation of workingmen, I have only further to say that institutions on the model of workingmen's clubs deserve to be encouraged in every possible way. Wealthy and benevolent persons could not do better with their means than to found such clubs where most required, and to endow them with a small annuity which would serve as a nucleus to club subscriptions, a greater number of subscribers being insured by the smaller amount of the fees. The Volunteer movement also deserves every encouragement, as supplying exercise and recreation to all classes at a very moderate cost.

Turning next to the recreation of women, I shall begin, as in the case of men, with the upper classes. And here, for the sake of emphasis, I shall confine my remarks to the one topic of muscular exercise. For ladies, more than any other section of the community, have fallen into the habit of neglecting exercise, and I am sure that I can not draw too dreadful a picture of the consequences which here arise from the too general custom. These consequences are all the more to be feared because many of them are of so insidious a kind that the root of the evil may never be suspected. It is not my intention to frighten any of the fair sex by unfolding a tale of horrors; so I will only say, in general terms, that I am quite sure among ladies there is no one source of disease and early death more prevalent than is this habitual violation of the best known among the laws of health. Consider for a moment what the life of a lady in town usually is. She rises probably at nine or ten o'clock, without much appetite for breakfast. Till luncheon she remains indoors, reading a novel or magazine, writing letters, or attending to her household duties. After luncheon she takes a little "carriage-exercise"—observe the unconscious irony of the term—pays a few afternoon calls, and returns home to afternoon tea. Until it is time to be dressed for dinner, there is another period

of total quiescence, and the tedious operations of the dressing-room which follow are certainly the reverse of recreation. Dinner in pleasant company no doubt affords recreation of a mental kind were such recreation required, which in this case it certainly is not. After dinner, during the season, she probably receives an evening party, goes to the opera, or indulges in some other kind of amusement which keeps her in hot rooms with vitiated air till the small hours of the morning. At last she retires to rest, complaining that her delicacy of constitution makes her a martyr to headaches, languid circulation, lassitude, and feelings of sickness. Now contrast such a wholly unnatural state of things with the daily life of a country girl to whom exercise is felt to be a *sine qua non* of existence, and do not wonder at the contrast between her state of blooming health and the feeble stamina of the lady whose position requires her to adopt the habits of town life. Ladies will no doubt tell me that these remarks are trite, and that they all knew before the desirability of taking exercise. I can only reply, if "ye knew these things happy are ye if you do them." And why not do them? Why not make the duty of taking daily exercise as important an article in your social creed as the duty of returning calls? If you say there is no time, the answer is preposterous. Senior wranglers could never have been senior wranglers had they not found time for their pull upon the Cam; and by not making time for exercise you are merely shortening the time of your life. Every day you can easily find time for a ride; or, if you are not able to ride, you may take every day a two hours' walk with some companion or object to make it a pleasurable walk. Such companions and objects are not difficult to obtain in the town; and in the country there are several kinds of outdoor amusements—such as rowing, riding, skating, lawn-tennis, etc.—which are happily recognized by the stern laws of etiquette as suitable for ladies, and which in performance are singularly graceful as well as highly conducive to good spirits. Dancing is also in itself an admirable form of exercise, though its beneficial effects are usually much more than counteracted by the late hours and excessive exhaustion of the ballroom. This excessive exhaustion of the muscular, but more especially of the nervous energies, may, in this as in all other similar cases, be properly denoted by the term which is the correlative of recreation—viz., dissipation. For although it has become customary to restrict the application of this term only to extreme cases, and to apply it to less extreme cases merely as a joke, both in etymology and in physiology the term dissipation is alike appropriate to all degrees of wasteful expenditure of the vital energies.

In recommending bodily exercise thus strongly, I speak of course to young and to middle-aged ladies; but I am sure that even here there are very few who could walk their five or six miles a day without fatigue. This merely shows to what a state of enervation their habitual neglect of exercise has reduced them. Such enfeebled per-

sons ought to begin at once to give their constitutions some chance of recovery; they ought regularly to take as much exercise as they can endure without distressing fatigue; and in a few months they would be surprised to find how greatly the length of their walks may be increased, and with what immense benefit they are attended.

Women in the lower classes of society may to a large extent share in the recreation of their male relatives; and I feel confident that the more those kinds of recreation are encouraged which invite participation by both sexes, the better. Great additional enjoyment is infused into a holiday if it can be spent in company with those most near and dear; the heart is then most open to the best influences of affection, and family ties are closest drawn in hours of happiness together. Such institutions as the Crystal and Alexandra Palaces, where a variety of amusements are provided at a cheap cost in country air and amid æsthetic surroundings, constitute the best type of institutions for the healthy and improving recreation of both sexes and all ages. Of parks and public pleasure-gardens I have already spoken, and the desirability of preserving commons and heaths in the near neighborhood of large towns is generally recognized. I will only add that no time ought to be lost in promoting the suggestion recently made to the First Commissioner of Public Works by the National Sunday League —viz., that in all such places of public resort harmless refreshments ought to be plentifully provided. As a type of more strictly town recreation, that which is afforded by the Polytechnic Institution deserves honorable mention, and the sustained popularity of the Moore and Burgess Minstrels' entertainment goes far to indicate that a much more healthy tone might be given to the entertainments which are generally provided by music-halls. Now that Cremorne Gardens, the Argyll Rooms, and similar places of public resort are being closed, there is certain to be a greater pressure of vice thrown upon the music-halls, and the increased demand for low, quasi-immoral entertainments which will thus be set up is only too certain to be supplied. It is greatly to be deplored that, excepting the "gods" galleries in theatres, there are now scarcely any places where respectable women of the lower classes can witness a public entertainment that is not more or less of a degrading kind. Philanthropists would do well to start in London several People's Theatres, where amusing dramas, part-singing, and other forms of innocent entertainment, would be sufficiently attractive to render the theatres self-supporting. I have no doubt that, if this were done, there would be a very marked distinction between the character of the audiences attending such theatres and that of the audiences which now attend the music-halls.

Before quitting the class of workingwomen, I must put in a good word for penny readings, mothers' meetings, window-gardening, and last, though not least, I should like to recommend some general and definite system for the loaning of books at a nominal cost.

We come now to the large and important class—children. It seems a mere commonplace to say that children ought to be allowed to run about and romp and play as much as ever they like or can. Yet this commonplace is far from having a common place in the usages of modern society. Among the upper classes children are much too frequently restrained from taking their full amount of natural play, either by preposterous ideas of genteel decorum, or by the respect due to expensive clothing; while among the lower classes the playground is too often restricted by the limits of the gutter, and even in the parks we too often witness the melancholy spectacle of children still a long way from their teens acting the part of nurse to still younger members of the family. To remedy these evils in the case of the upper classes there is nothing to suggest, except that fathers and mothers should cease to regard their children's clothes as of more importance than their children's health, and learn to estimate at its due value the responsibility of fostering the most precious of their possessions—these living, feeling, loving little ones whose capacities of life-long happiness are being molded by their parents' wisdom, or destroyed by their parents' folly. In the case of the lower classes, the *crèche*, or public nursery, where abundance of romping play is permitted, deserves the most strenuous encouragement. Children of all classes will play as they ought to play if only Nature is allowed to have her course without let or hindrance from artificial restraints.

But, as the only object in rearing children is not that of making them healthy animals, some amount of artificial restraint is necessary when the time for systematic mental training arrives. Nevertheless, as bodily health is the most essential condition even to mental training, the most fundamental principle which ought to guide the latter is that of supplying it with the minimum of cost to the former. Yet in school-life this fundamental principle is almost universally disregarded. So long as the general health of a school is maintained at a level compatible with work, and not below the level that declares itself by conspicuous "break-downs," so long nobody cares to reflect whether the system of school discipline is in all particulars the best for maintaining the general health at the highest possible level. I will not wait to consider the disgraceful food which, even in many of our better-class schools, is deemed sufficiently good for growing children to thrive upon; nor will I wait to inveigh against the system of competition which, when encouraged beyond moderate limits, acts as a baleful stimulus to the very pupils who least require to be stimulated. But, confining my remarks to the one particular of punishment, I should like to put it as a question of common sense, whether it would be possible to devise any mode of punishing school children at once more fatuous, more pernicious, or more opposed to every principle of science and morality, than are the modes which are now most generally in vogue. Consider for a moment the practice of giving "impositions."

It is not supposed that copying out a stated number of lines is an economical way of gaining information, so that even the plea of imparting instruction can not be advanced as a benefit to compensate the evil of the method. And this evil is a very serious one. The object of all our methods in education ought to be, as much as possible, to economize effort; the mental energies ought, as it were, to be nursed, so that by their exercise they should lay up the largest possible store of information. But the mental energy which is expended in writing out an imposition is wholly, or almost wholly, profitless; and the amount of energy so expended is considerable—especially in the case of long impositions. For the whole punishment of writing out an imposition consists in the *tediousness* of the process; and tediousness, by the painful class of emotions which it arouses, is the most wearisome or exhausting of the influences that consume the nervous energies. It may therefore be said that in whatever degree the writing of an imposition is a punishment, in that degree are the nervous energies dissipated in a wholly useless manner. Therefore, to say nothing of the actual time that is wasted in the writing of impositions, or of the slovenly style of handwriting which this mode of punishment induces, my great objection to the mode of punishment is that, by consuming the nervous energies in a wholly profitless manner, it stands in direct antagonism with all the principles that I am endeavoring to inculcate. And still more foolishly wrong does this method of punishment become when it is united, as it generally is, with another and still more objectionable method—I mean the custom of imprisoning children during playtime with the express purpose of denying them healthful recreation. To shut up a child already weary with work in an empty schoolroom under a depressing sense of disgrace, is something worse than cruel; to the child it is a wrongful injury that does not admit of being justified by any argument; and, in running counter to all the principles both of physiology and of education, it is a sin against society. In most cases the time during which a child is thus confined is the only time in the twenty-four hours that there is an opportunity afforded for any recreation at all; so that, when the weary time of solitude is over and school again meets, the unfortunate victim resumes work with energies doubly exhausted. Even if a child had the stamina of a man, it would be impossible that mental work resumed under such circumstances could be profitable—the faculty of memory being quickly affected by mental fatigue. But, as a matter of fact, owing to the great rapidity of physiological changes in a growing organism, a child has much more need of frequent exercise than has an adult; so that, whether we look at the matter from a sanitary or from an educational point of view, I think it is impossible too strongly to condemn the practice of confining school children during playtime.

Of course I shall be asked what modes of punishment I would suggest as substitutes for the two which I have thus so strongly con-

demned. This question, however, I am not careful to answer. Even if it is true that there is a difficulty in providing other and efficient modes of punishment, I should not feel the difficulty to justify the maintenance of modes that are so clearly injurious. But, merely for the sake of giving an answer, I may say that, in the case of girls, experience derived from many of the higher-class schools shows that discipline may be maintained, either without any punishment at all, or else by such kinds as are more nominal than real. The difficulty in the case of boys is no doubt greater, but not, I think, insurmountable. Many kinds of punishment may here be devised which go upon the principle, not of denying muscular exercise, but of enforcing it. Extra drills or other compulsory exercise during play-hours are modes of punishment greatly to be preferred to those involving sedentary confinement, although I do not pretend to insinuate that compulsory exercise in the way of punishment has the same recreative value as voluntary exercise in the way of play. For my own part, I have no hesitation in recommending corporal punishment as on all grounds greatly preferable to the protracted, tedious, heart-sickening, and health-breaking systems which, in the name of humanity, are coming more and more into general use. But, however great the difficulty of devising or substituting other modes of punishment may be, I feel sure there can be no reasonable doubt that the modes which are at present so largely in fashion ought to be universally abolished.

The above remarks of course apply almost exclusively to boys' schools; and, looking to boys' schools as a whole, but little more remains to be said of them in connection with recreation. The John Bull spirit of this country is in favor of allowing schoolboys to play the hardy and vigorous games which require all the muscles to be brought into active service. The case, however, is widely different in girls' schools; so, before concluding, I should like to add a few words with special reference to them.

School-life is the time when, most of all, healthful recreation is needed. It is then that the organism, being in a state of active growth, most requires the purifying and strengthening influences of muscular exercise to be in frequent operation; and the development which the organism, during the years of its growth, receives, is carried through its life as an unalterable possession. Yet in the majority of girls' schools how miserable is the provision that is made for securing this development! Even in our higher-class schools the whole mechanism of their discipline seems to be devised with the view of stemming the healthful flow of natural joyousness by the barriers of tedious monotony. On all sides a schoolgirl is shut up in a very prison-house of decorum; every healthful amusement is denied her as "unladylike"; she is imperatively taught to curb her youthful spirits in so far as these may sometimes be able to struggle above the weight of a mistaken discipline; she is nurtured during her growth on the

unhealthy soil of *ennui* in a depressing atmosphere of dullness; and, as too frequent a consequence, she leaves school with a sickly and enervated constitution, capable perhaps of high vivacity for a short time, but speedily collapsing under the strain of a few hours of bodily or mental activity. Now all this is the precise reverse of what school-life ought to be. The only aim of most of the higher girls' schools seems to be that of turning out pupils with a superficial knowledge of a variety of subjects, with such accomplishments as they may be able, by hard practice, to acquire, and with a well-drilled sense of the part that a young lady is to play in the complicated tragedy of etiquette. Now it is no doubt sufficiently desirable that girls, and especially young ladies, should be well educated; but, in my opinion, it is of far greater importance that schoolgirls should leave school with the maximum of bodily vigor that a wise and judicious nurture can impart, than that they should do so with minds educated to any level that you please to name within the limits of natural possibility. I should therefore like to see all girls' schools professedly regarded as places of recreation no less than as places of education—as places of bodily, no less than as places of mental culture. And, if this is considered too strong a statement of the case, it must at least be allowed that far more permanently beneficial work would be done by girls, both at school and after they leave it, if more permanently beneficial play were allowed. At present in most schools, with all indoor romping sternly forbidden as unladylike, all outdoor games regarded as impossible recreations for girls of their age and social position, the unfortunate prisoners are restricted in their exercise to a properly prison-like routine—a daily walk in twos and twos, all bound by the stiff chains of conventionality, with nothing to relieve the dull monotony of the well-known way, and one's constant companion being determined, not by any entertaining suitability of temperament, but by an accidental suitability of height. Could there be devised a more ludicrous caricature of all that we mean by recreation?

Do we want to know the remedy? The remedy is as simple as the abuse is patent. Let every school whose situation permits be provided with a good playground, and let every form of outdoor amusement be encouraged to the utmost. Schools situated in towns, and therefore unable to provide private playgrounds, might club together and rent a joint playground—care, of course, being taken that the social standing of all the schools which so club together should be about equal. Some such arrangement would soon be arrived at by town schools if parents generally would bestow more thought on the importance of their children's health, and turn a deaf ear to all the qualifications of a school, however good, which does not provide for the proper recreation of its pupils.

Of course I shall be met by the objection that, by encouraging active outdoor games among schoolgirls, we should rub off the bloom,

so to speak, of refinement, and that, as a result, we should tend to impair the delicate growth of that which we all recognize as of paramount value in education—good breeding. I can only say I am fully persuaded, by the results I have seen, that such would not be the case. The feelings and the manners of a lady are imparted by inheritance and by the society in which she lives, and no amount of drilling by schoolmistresses will produce more than an artificial imitation of the natural reality. Therefore, once let a girls' school be a little society of little ladies, and we need never fear that active play, natural to their age and essential to their health, will make them less ladylike than does the stiff restraint of the present system. Rather would active play, during the years of bodily growth, by developing the coördinated use of all the muscles, tend to impart through after-life that grace of easy movement which we all admire, but the secret of which is truly revealed only to the children of nature.

So much, then, for bodily recreation in girls' schools. As regards their mental recreation, I should begin by recommending less mental work. In most of the higher-class girls' schools, as in boys' schools, a great deal more work is required than it is either judicious or desirable to require. The root of this evil is that a girl's education is usually made to terminate at the age of seventeen or eighteen, and, as a consequence, she is expected to gain during these early years of life a sufficient amount of book-learning to serve for the rest of her days. In many cases it is, no doubt, unavoidable that a girl's education should end when she leaves school; but I think that, in all cases, education ought to be less arduous than it is in many of our girls' schools. Even if education is to end with school-life, it is better that it should end with a little knowledge thoroughly acquired, than with a confused and half-forgotten medley of many subjects. Not that I advocate specialty and depth of knowledge for girls. On the contrary, I think that the aim here ought rather to be that of generality and width—languages, elementary mathematics, geography, history, art, science, and English literature being all taught, but taught superficially, or without much detail, and in as entertaining a manner as possible. The point, however, which I desire chiefly to insist upon is this, that schoolgirls ought not to be made or encouraged to work beyond their strength. In most girls' schools competition runs very high; and I am quite sure that in very many cases the aim of the schoolmistress ought to be to check its undue severity, rather than to stimulate that severity by competitive examinations. I have myself known many cases of girls sitting up late, rising early, and working all day to win their coveted prizes—a state of things which is a sufficiently crying evil even in boys' schools, but which is a still worse evil in girls—worse because the physique of a girl is usually less robust than that of a boy, and because the schoolgirl is doomed to a smaller amount of outdoor exercise.

Now, if less time were consumed in girls' schools by mental work, more time would be allowed for mental as well as for bodily recreation. And, if the time thus gained were judiciously expended, I believe that, even as a matter of mental culture, more would be gained than lost. Suppose, for instance, that some time in every day were set apart for mental occupation of a voluntary kind—a good library of general though selected literature being provided for the use of the pupils, and the cultivation of art being allowed to rank as "mental occupation." In this way the more intellectual of the pupils would be able to receive that culture which only general reading can impart, the more artistic would be able to improve themselves in their art by additional practice, and even the unstudiously disposed would find in a standard novel a kind of reading less distasteful than Euclid.

And here, while treating of mental recreation among girls, I may add that school-life is the time when provision ought to be made for mental recreation in after-life. Be it observed that mental recreation is impossible unless there is a natural and more or less cultured taste for some branch or branches of mental work. Indeed, the capacity for such recreation is clearly proportional to the degree of such culture—an idealess mind being incapacitated for obtaining any *variety* of ideas. Hence the great importance of width of cultured interest, and the consequent duty of the heads of schools to ascertain the mental predilections of their pupils individually, and, in each case where such a predilection is apparent, to bestow special attention on its culture. If this were more generally done, I am convinced that the gain to their pupils in after-life would be enormous. We are living in a world teeming with interest on every side, but to make this interest our own possession we require a trained intelligence. It ought, therefore, to be one of the first aims of education to supply special training to special aptitudes, whereby the mind may be brought *en rapport* with the things in which it is by nature fitted to take most interest, and so in them to find a never-ending source of mental recreation. If this method were more universally adopted in girls' schools, ladies as a rule would be supplied with more internal resources of mental activity and cease to be so dependent for the stimulation of such activity on the mere excitement which is supplied by the external resources of society. But as it is, whether in the concert-room, the picture-gallery, the library, or the country walk, it is of most ladies literally and lamentably true, that having eyes they see not, and having ears they hear not, neither understand. Most ladies have a natural taste for some one or other of the many lines of intellectual activity, and if this taste were developed in early life it would grow with the knowledge on which it feeds, till in mature life it would become an unfailing source of pleasurable recreation. Yet in most cases such a taste in early life is not so much as discovered. For instance, how seldom it is that we meet, even among musical ladies, with any knowledge of harmony!

—and this simply because they have never ascertained whether the study of harmony might not be to them a study of absorbing interest. Or, again, how very rare a thing it is to meet a lady who has even a superficial acquaintance with any one of the sciences; and how vast is the paradise of intellectual enjoyment from which multitudes of intelligent ladies are thus excluded! And similarly with all the other lines of intellectual pursuit for which a certain small amount of rudimentary initiation is required in order to ascertain whether they are suited to individual taste. So that, as I have said, one of the most important aims of a girl's, and also of a boy's, education ought to be to ascertain and specially to cultivate the branch of knowledge in which most interest is taken. Let us not suppose that by following this advice there is any danger of imparting to young ladies that singularly objectionable and not very easily definable character which is most tersely and intelligently conveyed by the word "blue." No one can have a more intense dislike than I have of the cerulean tint; but, wherever I have seen it, I have always been persuaded that it is the previous character which has tinted the learning—not the learning which has tinted the character. Only let a lady be a lady, and nothing but envious ignorance can ever venture to breathe the objectionable word, while cultured refinement in the opposite sex will always discover in the culture of a lady that only which adds to her refinement.

I have now said all that I feel it desirable to say on the principles and the practice of recreation; and I will conclude by adding a few words on what I may call the ethics of recreation.

Health may be taken as implying capacity for work, as well as to a large, though to a less absolute degree, the capacity for happiness; and, as duty means our obligation to promote the general happiness, it follows that in no connection is the voice of duty more urgent than it is in the advancement of all that is conducive to health. By maintaining our own health at the highest point of its natural efficiency, we are doing all that in us lies to secure for ourselves the prime condition for work—that is, the prime condition for benefiting the community to whatever extent our powers may be capable. And, similarly, by promoting the health of others, we are, in proportion to our success, securing to the community a certain amount of additional capacity for work on the part of its constituent members, as well as increasing the individual capacity for happiness on the part of all the members whom our efforts may reach. Therefore, I take it that, if we regard this subject from an ethical point of view, it is clear that we have no duty to perform of a more grave and important kind than this—thoughtfully to study the conditions of health, earnestly to teach these conditions to others, and strenuously to make their observance a law to ourselves. Now, of these conditions one of the most important is suitable recreation. For this is the condition which extends to all classes of the community, and the observance of which is, as we have

seen, an imperative necessity to every individual who desires to possess a sound working mind in a sound working body. Hence I do not hesitate to say that one of our most weighty duties in life is to ascertain the kinds and degrees of recreation which are most suitable to ourselves or to others, and then with all our hearts to utilize the one, while with all our powers we encourage the other. Be it remembered that by recreation I mean only that which with the least expenditure of time renders the exhausted energies most fitted to resume their work; and be it also remembered that recreation is necessary not only for maintaining our powers of work so far as these are dependent on our vitality, but also for maintaining our happiness so far as this is dependent on our health. Remembering these things, I entertain no fear of contradiction when I conclude that, whether we look to the community as a whole, or restrict our view to our own individual selves, we have no duty to discharge of a more high and serious kind than this—rationally to understand and properly to apply the principles of all that in the full but only legitimate sense of the word we call recreation. Again, therefore, I say, if we know these things, happy are we if we do them. And if we desire to do them—if as rational and moral creatures we desire to obey the most solemn injunction that ever fell from human lips, "Work while it is day"—we must remember that the daylight of our life may be clouded by our folly or shortened by our sin; that the work which we may hope to do we shall be enabled to do only by hearkening to that Wisdom who holdeth in her right hand length of days, in her left hand riches and honor; and that at last, when all to us is dark with the darkness of an unknown night, such Wisdom will not have cried to us in vain, if she has taught us how to sow most plenteously a harvest of good things that our children's children are to reap.—*Nineteenth Century.*

MYTHOLOGIC PHILOSOPHY.*

By Major J. W. POWELL.

I.—The Genesis of Philosophy.

THE wonders of the course of nature have ever challenged attention. In savagery, in barbarism, and in civilization alike, the mind of man has sought the explanation of things. The movements of the heavenly bodies, the change of seasons, the succession of night and day, the powers of the air, majestic mountains, ever-flowing rivers, perennial springs, the flight of birds, the gliding of serpents,

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the growth of trees, the blooming of flowers, the forms of storm-carved rocks, the mysteries of life and death, the institutions of society—many are the things to be explained. The yearning to know is universal. *How* and *why* are everlasting interrogatories profoundly instinct in humanity. In the evolution of the human mind, the instinct of cosmic interrogation follows hard upon the instinct of self-preservation.

In all the operations of nature, man's weal and woe are involved. A cold wave sweeps from the north—rivers and lakes are frozen, forests are buried under snows, and the fierce winds almost congeal the life-fluids of man himself, and indeed man's sources of supply are buried under the rocks of water. At another time the heavens are as brass, and the clouds come and go with mockery of unfulfilled promises of rain, the fierce midsummer sun pours its beams upon the sands, and scorching blasts heated in the furnace of the desert sear the vegetation, and the fruits, which in more congenial seasons are subsistence and luxury, shrivel before the eyes of famishing men. A river rages and destroys the adjacent valley with its flood. A mountain bursts forth with its rivers of fire, the land is buried and the people are swept away. Lightning shivers a tree and rends a skull. The silent, unseen powers of nature, too, are at work bringing pain or joy, health or sickness, life or death, to mankind. In like manner man's welfare is involved in all the institutions of society. *How* and *why* are the questions asked about all these things—questions springing from the deepest instinct of self-preservation.

In all stages of savage, barbaric, and civilized inquiry every question has found an answer, every *how* has had its *thus*, every *why* its *because*. The sum of the answers to the questions raised by any people constitute its philosophy; hence all peoples have had philosophies consisting of their accepted explanation of things. Such a philosophy must necessarily result from the primary instincts developed in man in the early progress of his differentiation from the beast. This I postulate; if demonstration is necessary, demonstration is at hand. Not only has every people a philosophy, but every stage of culture is characterized by its stage of philosophy. Philosophy has been unfolded with the evolution of the human understanding. The history of philosophy is the history of human opinions from the earlier to the later days—from the lower to the higher culture.

In the production of a philosophy phenomena must be discerned, discriminated, classified. Discernment, discrimination, and classification are the processes by which a philosophy is developed. In studying the philosophy of a people at any stage of culture, to understand what such a people entertain as the sum of their knowledge it is necessary that we should understand what phenomena they saw, heard, felt, discerned; what discriminations they made, and what resemblances they seized upon as a basis for the classification on which

their explanations rested. A philosophy will be higher in the scale, nearer the truth, as the discernment is wider, the discrimination nicer, and the classification better.

The sense of the savage is dull compared with the sense of the civilized man. There is a myth current in civilization to the effect that the barbarian has highly developed perceptive faculties. It has no more foundation than the myth of the wisdom of the owl. A savage sees but few sights, hears but few sounds, tastes but few flavors, smells but few odors; his whole sensuous life is narrow and blunt, and his facts that are made up of the combination of sensuous impressions are few. In comparison the civilized man has his vision extended away toward the infinitesimal and away toward the infinite; his perception of sound is multiplied to the comprehension of rapturous symphonies; his perception of taste is increased to the enjoyment of delicious viands; his perception of smell is developed to the appreciation of most exquisite perfumes; and his facts that are made up of the combination of sensuous impressions are multiplied beyond enumeration. The stages of discernment from the lowest savage to the highest civilized man constitute a series the end of which is far from the beginning.

If the discernment of the savage is little, his discrimination is less. All his sensuous perceptions are confused; but the confusion is that universal habit of savagery—the confusion of the objective with the subjective, so that the savage sees, hears, tastes, smells, feels the imaginings of his own mind. Subjectively determined sensuous processes are diseases in civilization, but normal functional methods in savagery.

The savage philosopher classifies by obvious resemblances—analogic characters. The civilized philosopher classifies by essential affinities—homologic characteristics—and the progress of philosophy is marked by changes from analogic categories to homologic categories.

II.—Two Grand Stages of Philosophy.

There are two grand stages of philosophy—the mythologic and the scientific. In the first, all phenomena are explained by analogies derived from subjective human experiences; in the latter, phenomena are explained as orderly successions of events.

In sublime egotism man first interprets the cosmos as an extension of himself; he classifies the phenomena of the outer world by their analogies with subjective phenomena; his measure of distance is his own pace, his measure of time his own sleep, for he says, "It is a thousand paces to the great rock," or, "It is a hundred sleeps to the great feast." Noises are voices, powers are hands, movements are made afoot. By subjective examination discovering in himself will and design, and by inductive reason discovering will and design in his fellow men and in animals, he extends the induction to all the cosmos,

and there discovers in all things will and design. All phenomena are supposed to be the acts of some one, and that some one having will and purpose. In mythologic philosophy the phenomena of the outer physical world are supposed to be the acts of living, willing, designing personages. The simple are compared with and explained by the complex. In scientific philosophy, phenomena are supposed to be children of antecedent phenomena, and so far as science goes with its explanation they are thus interpreted. Man with the subjective phenomena gathered about him is studied from an objective point of view, and the phenomena of subjective life are relegated to the categories established in the classification of the phenomena of the outer world; thus the complex is studied by resolving it into its simple constituents.

Some examples of the philosophic methods belonging to widely separated grades of culture may serve to make my statements clearer.

Wind.—The Ute philosopher discerns that men and animals breathe. He recognizes vaguely the phenomena of the wind, and discovers its resemblance to breath, and explains the winds by relegating them to the class of breathings. He declares that there is a monster beast in the north that breathes the winter winds, and another in the south, and another in the east, and another in the west. The facts relating to winds are but partially discerned; the philosopher has not yet discovered that there is an earth-surrounding atmosphere. He fails also in making the proper discriminations. His relegation of the winds to the class of breathings is analogic, but not homologic. The basis of his philosophy is personality, and hence he has four wind-gods.

The philosopher of the ancient Northland discovered that he could cool his brow with a fan, or kindle a flame, or sweep away the dust with the wafted air. The winds also cooled his brow, the winds also swept away the dust and kindled the fire into a great conflagration, and when the wind blew he said, "Somebody is fanning the waters of the fiord," or "Somebody is fanning the evergreen forests," and he relegated the winds to the class of fannings, and he said, "The god Hraesvelger, clothed with eagle-plumes, is spreading his wings for flight, and the winds rise from under them."

The early Greek philosopher discovered that air may be imprisoned in vessels or move in the ventilation of caves, and he recognized wind as something more than breath, something more than fanning, something that can be gathered up and scattered abroad, and so when the winds blew he said, "The sacks have been untied," or "The caves have been opened."

The philosopher of civilization has discovered that breath, the fan-wafted breeze, the air confined in vessels, the air moving in ventilation—that these are all parts of the great body of air which surrounds the earth, all in motion, swung by the revolving earth, heated at the tropics, cooled at the poles, and thus turned into counter-cur-

rents and again deflected by a thousand geographic features, so that the winds sweep down valleys, eddy among mountain-crags, or waft the spray from the crested billows of the sea, all in obedience to cosmic laws. The facts discerned are many, the discriminations made are nice, and the classifications based on true homologies, and we have the science of meteorology, which exhibits an orderly succession of events even in the fickle winds.

Sun and Moon.—The Ute philosopher declares the sun to be a living personage, and explains his passage across the heavens along an appointed way by giving an account of a fierce personal conflict between Ta-vi, the sun-god, and Ta-wats, one of the supreme gods of his mythology.

In that long ago, the time to which all mythology refers, the sun roamed the earth at will. When he came too near with his fierce heat the people were scorched, and when he hid away in his cave for a long time, too idle to come forth, the night was long and the earth cold. Once upon a time Ta-wats, the hare-god, was sitting with his family by the camp-fire in the solemn woods, anxiously waiting for the return of Ta-vi, the wayward sun-god. Wearied with long watching, the hare-god fell asleep, and the sun-god came so near that he scorched the naked shoulder of Ta-wats. Foreseeing the vengeance which would be thus provoked, he fled back to his cave beneath the earth. Ta-wats awoke in great anger, and speedily determined to go and fight the sun-god. After a long journey of many adventures the hare-god came to the brink of the earth, and there watched long and patiently, till at last the sun-god coming out he shot an arrow at his face, but the fierce heat consumed the arrow ere it had finished its intended course; then another arrow was sped, but that also was consumed; and another, and still another, till only one remained in his quiver, but this was the magical arrow that had never failed its mark. Ta-wats, holding it in his hand, lifted the barb to his eye and baptized it in a divine tear; then the arrow was sped and struck the sun-god full in the face, and the sun was shivered into a thousand fragments, which fell to the earth, causing a general conflagration. Then Ta-wats, the hare-god, fled before the destruction he had wrought, and as he fled the burning earth consumed his feet, consumed his legs, consumed his body, consumed his hands and his arms—all were consumed but the head alone, which bowled across valleys and over mountains, fleeing destruction from the burning earth until at last, swollen with heat, the eyes of the god burst and the tears gushed forth in a flood which spread over the earth and extinguished the fire. The sun-god was now conquered, and he appeared before a council of the gods to await sentence. In that long council were established the days and the nights, the seasons and the years, with the length thereof, and the sun was condemned to travel across the firmament by the same trail day after day till the end of time.

In this same philosophy we learn that in that ancient time a council of the gods was held to consider the propriety of making a moon, and at last the task was given to Whippoorwill, a god of the night, and a frog yielded himself a willing sacrifice for this purpose, and the Whippoorwill, by incantations, and other magical means, transformed the frog into the new moon. The truth of this origin of the moon is made evident to our very senses; for do we not see the frog riding the moon at night, and the moon is cold, because the frog from which it was made was cold?

The philosopher of Oraibi tells us that when the people ascended by means of the magical tree which constituted the ladder from the lower world to this, they found the firmament, the ceiling of this world, low down upon the earth—the floor of this world. Machito, one of their gods, raised the firmament on his shoulders to where it is now seen. Still the world was dark, as there was no sun, no moon, and no stars. So the people murmured because of the darkness and the cold. Machito said, "Bring me seven maidens," and they brought him seven maidens; and he said, "Bring me seven baskets of cotton-bolls," and they brought him seven baskets of cotton-bolls; and he taught the seven maidens to weave a magical fabric from the cotton, and when they had finished it he held it aloft, and the breeze carried it away toward the firmament, and in the twinkling of an eye it was transformed into a beautiful full-orbed moon, and the same breeze caught the remnants of flocculent cotton which the maidens had scattered during their work, and carried them aloft, and they were transformed into bright stars. But still it was cold, and the people murmured again, and Machito said, "Bring me seven buffalo-robes," and they brought him seven buffalo-robes, and from the densely matted hair of the robes he wove another wonderful fabric, which the storm carried away into the sky, and it was transformed into the full-orbed sun. Then Machito appointed times and seasons, and ways for the heavenly bodies, and the gods of the firmament have obeyed the injunctions of Machito from the day of their creation to the present.

The Norse philosopher tells us that Night and Day, each, has a horse and a car, and they drive successively one after the other around the world in twenty-four hours. Night rides first with her steed named Dew-hair, and every morning as he ends his course he bedews the earth with foam from his bit. The steed driven by Day is Shining-hair. All the sky and earth glisten with the light of his mane. Jarnved, the great iron-wood forest lying to the east of Midgard, is the abode of a race of witches. One monster witch is the mother of many sons in the form of wolves, two of which are Skol and Hate. Skol is the wolf that would devour the maiden Sun, and she daily flies from the maw of the terrible beast, and the moon-man flies from the wolf Hate.

The philosopher of Samos tells us that the earth is surrounded by hollow crystalline spheres set one within another, and all revolving at

different rates from east to west about the earth, and that the sun is set in one of these spheres and the moon in another.

The philosopher of civilization tells us that the sun is an incandescent globe, one of the millions afloat in space. About this globe the planets revolve, and the sun and planets and moons were formed from nebulous matter by the gradual segregation of their particles controlled by the laws of gravity, motion, and affinity. The sun, traveling by an appointed way across the heavens with the never-ending succession of day and night, and the ever-recurring train of seasons, is one of the subjects of every philosophy. Among all peoples, in all times, there is an explanation of these phenomena, but in the lowest stage, way down in savagery, how few the facts discerned, how vague the discriminations made, how superficial the resemblances by which the phenomena are classified! In this stage of culture, all the daily and monthly and yearly phenomena which come as the direct result of the movements of the heavenly bodies are interpreted as the doings of some one—some god acts. In civilization the philosopher presents us the science of astronomy with all its accumulated facts of magnitude, and weights, and orbits, and distances, and velocities—with all the nice discriminations of absolute, relative, and apparent motions; and all these facts he is endeavoring to classify in homologic categories, and the evolutions and revolutions of the heavenly bodies are explained as an orderly succession of events.

Rain.—The Shoshone philosopher believes the domed firmament to be ice, and surely it is the very color of ice, and he believes further that a monster serpent-god coils his huge back to the firmament and with his scales abrades its face and causes the ice-dust to fall upon the earth. In the winter-time it falls as snow, but in the summer-time it melts and falls as rain, and the Shoshone philosopher actually sees the serpent of the storm in the rainbow of many colors.

The Oraibi philosopher who lives in a *pueblo* is acquainted with architecture, and so his world is seven-storied. There is a world below and five worlds above this one. Muingwa, the rain-god who lives in the world immediately above, dips his great brush made of feathers of the birds of the heavens into the lakes of the skies and sprinkles the earth with refreshing rain for the irrigation of the crops tilled by these curious Indians who live on the cliffs of Arizona. In winter, Muningwa crushes the ice of the lakes of the heavens and scatters it over the earth, and we have a snow-fall.

The Hindoo philosopher says that the lightning-bearded Indra breaks the vessels that hold the waters of the skies with his thunderbolts, and the rains descend to irrigate the earth.

The philosopher of civilization expounds to us the methods by which the waters are evaporated from the land and the surface of the sea, and carried away by the winds, and gathered into clouds to be discharged again upon the earth, keeping up for ever that wonderful

circulation of water from the heavens to the earth, and from the earth to the heavens—that orderly succession of events in which the waters travel by river, by sea, and by cloud.

Rainbow.—In Shoshone, the rainbow is a beautiful serpent that abrades the firmament of ice to give us snow and rain. In Norse, the rainbow is the bridge Bifrost spanning the space between heaven and earth. In the Iliad, the rainbow is the goddess Iris, the messenger of the King of Olympus. In Hebrew, the rainbow is the witness to a covenant. In science, the rainbow is an analysis of white light into its constituent colors by the refraction of rain-drops.

Falling Stars.—In Ute, falling stars are the excrements of dirty little star-gods. In science—well, I do not know what falling stars are in science. I think they are cinders from the furnaces where the worlds are forged. You may call this mythologic or scientific, as you please.

Migration of Birds.—The Algonquin philosopher explains the migration of birds by relating the myth of the combat between Ka-bi-bo-no-ke and Shingapis, the prototype or progenitor of the water-hen, one of their animal gods. A fierce battle raged between Ka-bi-bo-no-ke and Shingapis, but the latter could not be conquered. All the birds were driven from the land but Shingapis; and then was it established that whenever in the future Winter-maker should come with his cold winds, fierce snows, and frozen waters, all the birds should leave for the south except Shingapis and his friends. So the birds that spend their winters north are called by the Algonquin philosophers "the friends of Shingapis."

In contrast to this explanation of the flight of birds may be placed the explanation of the modern evolutionist, who says that the birds migrate in quest of abundance of food and a genial climate, guided by an instinct of migration, which is an accumulation of inherited memories.

Diversity of Languages.—The Kaibabit philosopher accounts for the diversity of languages in this manner: Si-chom-pa Ma-so-its, the grandmother goddess of the sea, brought up mankind from beneath the waves in a sack, which she delivered to the Shi-nau-av brothers, the great wolf-gods of his mythology, and told them to carry it from the shores of the sea to the Kaibab Plateau, and then to open it; but they were by no means to open the package ere their arrival, lest some great disaster should befall. The curiosity of the younger Shi-nau-av overcame him, and he untied the sack and the people swarmed out; but the elder Shi-nau-av, the wiser god, ran back and closed the sack while yet not all the people had escaped, and they carried the sack, with its remaining contents, to the plateau, and there opened it. Those that remained in the sack found a beautiful land—a great plateau covered with mighty forests, through which elk, deer, and antelope roamed in abundance, and many mountain-sheep were found on the

bordering crags; *pive*, the nuts of the edible pine, they found on the foot-hills, and *use*, the fruit of the *yucca*, in sunny glades—and *nant*, the *meschal* crowns, for their feasts—and *chuar*, the cactus-apple, from which to make their wine; reeds grew about the lakes for their arrow-shafts; the rocks were full of flints for their barbs and knives, and away down in the cañon they found a pipe-stone quarry, and on the hills they found *arraumpive*, their tobacco. Oh, it was a beautiful land that was given to these, the favorites of the gods! The descendants of these people are the present Kaibabits of northern Arizona. Those who escaped by the way, through the wicked curiosity of the younger Shi-nau-av, scattered over the country and became Navajos, Moquis, Sioux, Comanches, Spaniards, Americans—poor, sorry fragments of people without the original language of the gods, and only able to talk in imperfect jargons.

The Hebrew philosopher tells us that on the plains of Shinar the people of the world were gathered to build a city and erect a tower the summit of which should reach above the waves of any flood Jehovah might send. But their tongues were confused as a punishment for their impiety.

The philosopher of science tells us that mankind was widely scattered over the earth anterior to the development of articulate speech, that the languages of which we are cognizant sprung from innumerable centers as each little tribe developed its own language, and that in the study of any language an orderly succession of events may be discovered in its evolution from a few simple holophrastic locutions to a complex language with a multiplicity of words and an elaborate grammatic structure, by the differentiation of the parts of speech and the integration of the sentence.

A Cough.—A man coughs. In explanation the Ute philosopher would tell us that an *unupits*—a pygmy spirit of evil—had entered the poor man's stomach, and he would charge the invalid with having whistled at night; for in their philosophy it is taught that if a man whistles at night, when the pygmy spirits are abroad, one is sure to go through the open door into the stomach, and the evidence of this disaster is found in the cough which the *unupits* causes. Then the evil spirit must be driven out, and the medicine-man stretches his patient on the ground and scarifies him with the claws of eagles from head to heel, and while performing the scarification a group of men and women stand about, forming a chorus, and medicine-man and chorus perform a fugue in gloomy ululation, for these wicked spirits will depart only by incantations and scarifications. In our folk-lore philosophy a cough is caused by a "cold," whatever that may be—a vague entity—that must be treated first according to the maxim "Feed a cold and starve a fever," and the "cold" is driven away by potations of bitter teas.

In our medical philosophy a cough may be the result of a clogging

of the pores of the skin, and is relieved by clearing those flues that carry away the waste products of vital combustion.

These illustrations are perhaps sufficient to exhibit the principal characteristics of the two methods of philosophy, and, though they cover but narrow fields, it should be remembered that every philosophy deals with the whole cosmos. An explanation of all things is sought —not alone the great movements of the heavens, or the phenomena that startle even the unthinking, but every particular which is observed. Abstractly, the plane of demarkation between the two methods of philosophy can be sharply drawn, but practically we find them strangely mixed; mythologic methods prevail in savagery and barbarism, and scientific methods prevail in civilization. Mythologic philosophies antedate scientific philosophies. The thaumaturgic phases of mythology are the embryonic stages of philosophy, science being the fully developed form. Without mythology there could be no science, as without childhood there could be no manhood, or without embryonic conditions there could be no ultimate forms.

III.—Mythologic Philosophy has Four Stages.

Mythologic philosophy is the subject with which we deal. Its method, as stated in general terms, is this: All phenomena of the outer objective world are interpreted by comparison with those of the inner subjective world. Whatever happens, some one does it—that some one has a will and works as he wills. The basis of the philosophy is personality. The persons who do the things which we observe in the phenomena of the universe are the gods of mythology—*the cosmos is a pantheon*. Under this system, whatever may be the phenomenon observed, the philosopher asks, "Who does it?" and "Why?" and the answer comes, "A god with his design." The winds blow, and the interrogatory is answered, "Æolus frees them from the cave to speed the ship of a friend, or destroy the vessel of a foe." The actors in mythologic philosophy are gods.

In the character of these gods four stages of philosophy may be discovered. In the lowest and earliest stage everything has life, everything is endowed with personality, will, and design: animals are endowed with all the wonderful attributes of mankind; all inanimate objects are believed to be animate; trees think and speak; stones have loves and hates; hills and mountains, springs and rivers, and all the bright stars, have life—everything discovered objectively by the senses is looked upon subjectively by the philosopher and endowed with all the attributes supposed to be inherent in himself. In this stage of philosophy everything is a god. Let us call it *hecastotheism*.

In the second stage men no longer attribute life indiscriminately to inanimate things; but the same powers and attributes recognized by subjective vision in man are attributed to the animals by which he is surrounded. No line of demarkation is drawn between man and

beast; all are great beings endowed with wonderful attributes. Let us call this stage *zoötheism*, when men worship beasts. All the phenomena of nature are the doings of these animal gods, all the facts of nature, all the phenomena of the known universe, all the institutions of humanity known to the philosophers of this stage, are accounted for in the mythologic history of these zoömorphic gods.

In the third stage a wide gulf is placed between man and the lower animals. The animal gods are dethroned, and the powers and phenomena of nature are personified and deified. Let us call this stage *physitheism*. The gods are strictly anthropomorphic, having the form as well as the mental, moral, and social attributes of men. Thus we have a god of the sun, a god of the moon, a god of the air, a god of dawn, and a deity of the night.

In the fourth stage, mental, moral, and social characteristics are personified and deified. Thus we have a god of war, a god of love, a god of revelry, a god of plenty, and like personages who preside over the institutions and occupations of mankind. Let us call this *psychotheism*. With the mental, moral, and social characteristics in these gods are associated the powers of nature; and they differ from nature-gods chiefly in that they have more distinct psychic characteristics.

Psychotheism, by the processes of mental integration, develops in one direction into monotheism, and in the other into pantheism. When the powers of nature are held predominant in the minds of the philosophers through whose cogitations this evolution of theism is carried on, pantheism, as the highest form of psychotheism, is the final result; but when the moral qualities are held in highest regard in the minds of the men in whom this process of evolution is carried on, *monotheism*, or a god whose essential characteristics are moral qualities, is the final product. The monotheistic god is not nature, but presides over and operates through nature. Psychotheism has long been recognized. All of the earlier literature of mankind treats largely of these gods, for it is an interesting fact that in the history of any civilized people, the evolution of psychotheism is approximately synchronous with the invention of an alphabet. In the earliest writings of the Egyptians, the Hindoos, and the Greeks, this stage is discovered, and Osiris, Indra, and Zeus are characteristic representatives. As psychotheism and written language appear together in the evolution of culture, this stage of theism is consciously or unconsciously a part of the theme of all written history.

The paleontologist, in studying the rocks of the hill and the cliffs of the mountain, discovers, in inanimate stones, the life-forms of the ancient earth. The geologist, in the study of the structure of valleys and mountains, discovers groups of facts that lead him to a knowledge of more ancient mountains and valleys and seas, of geographic features long ago buried, and followed by a new land with new mountains and valleys, and new seas. The philologist, in studying the earliest writ-

ings of a people, not only discovers the thoughts purposely recorded in those writings, but is able to go back in the history of the people many generations, and discover with even greater certainty the thoughts of the more ancient people who made the words. Thus the writings of the Greeks, the Hindoos, and the Egyptians, that give an account of their psychic gods, also contain a description of an earlier theism unconsciously recorded by the writers themselves. Psychotheism prevailed when the sentences were coined, physitheism when the words were coined. So the philologist discovers physitheism in all ancient literature. But the verity of that stage of philosophy does not rest alone upon the evidence derived from the study of fossil philosophies through the science of philology. In the folk-lore of every civilized people having a psychotheic philosophy, an earlier philosophy with nature-gods is discovered.

The different stages of philosophy which I have attempted to characterize have never been found in purity. We always observe different methods of explanation existing side by side, and the type of a philosophy is determined by the prevailing characteristics of its explanation of phenomena. Fragments of earlier are always found side by side with the greater body of the later philosophy. Man has never clothed himself in new garments of wisdom, but has for ever been patching the old, and the old and the new are blended in the same pattern, and thus we have atavism in philosophy. So in the study of any philosophy which has reached the psychotheic age, patches of the earlier philosophy are always seen. Ancient nature-gods are found to be living and associating with the supreme psychic deities. Thus in anthropological science there are three ways by which to go back in the history of any civilized people and learn of its barbaric physitheism. But of the verity of this stage we have further evidence. When Christianity was carried north from central Europe, the champions of the new philosophy, and its consequent religion, discovered, among those who dwelt by the glaciers of the north, a barbaric philosophy which they have preserved to history in the Eddas and Sagas, and Norse literature is full of a philosophy in a transition state, from physitheism to psychotheism; and, mark! the people discovered in this transition state were inventing an alphabet—they were carving Runes. Then a pure physitheism was discovered in the Aztec barbarism of Mexico, and elsewhere on the globe many people were found in that stage of culture to which this philosophy properly belongs. Thus the existence of physitheism as a stage of philosophy is abundantly attested. Comparative mythologists are agreed in recognizing these two stages. They might not agree to throw all of the higher and later philosophies into one group, as I have done, but all recognize the plane of demarkation between the higher and the lower groups as I have drawn it. Scholars, too, have come essentially to an agreement that physitheism is earlier and older than psychotheism. Perhaps there

may be left a "doubting Thomas" who believes that the highest stage of psychotheism—that is, monotheism—was the original basis for the philosophy of the world, and that all other forms are degeneracies from that primitive and perfect state. If there be such a man left, to him what I have to say about philosophy is blasphemy.

Again, all students of comparative philosophy, or comparative mythology, or comparative religion, as you may please to approach this subject from different points of view, recognize that there is something else; that there are philosophies, or mythologies, or religions, not included in the two great groups. All that something else has been vaguely called *fetichism*. I have divided it into two parts, *hecastotheism* and *zoötheism*. The verity of zoötheism as a stage of philosophy rests on abundant evidence. In psychotheism it appears as *devilism* in obedience to a well-known law of comparative theology, viz., that the gods of a lower and superseded stage of culture oftentimes become the devils of a higher stage. So in the very highest stages of psychotheism we find beast-devils. In Norse mythology, we have Fenris the wolf, and Jormungandur the serpent. Dragons appear in Greek mythology, the bull is an Egyptian god, a serpent is found in the Zendavesta; and was there not a scaly fellow in the garden of Eden? So common are these beast-demons in the higher mythologies that they are used in every literature as rhetorical figures. So we find, as a figure of speech, the great red dragon with seven heads and ten horns, with tail that with one brush sweeps away a third of the stars of heaven. And wherever we find nature-worship we find it accompanied with beast-worship. In the study of higher philosophies, having learned that lower philosophies often exist side by side with them, we might legitimately conclude that a philosophy based upon animal gods had existed previous to the development of physitheism; and philologic research leads to the same conclusion. But we are not left to base this conclusion upon an induction only, for in the examination of savage philosophies we actually discover zoötheism in all its proportions. Many of the Indians of North America, and many of South America, and many of the tribes of Africa, are found to be zoötheists. Their supreme gods are animals—tigers, bears, wolves, serpents, birds. Having discovered this, with a vast accumulation of evidence, we are enabled to carry philosophy back one stage beyond physitheism, and we can confidently assert that all of the philosophies of civilization have come up through these three stages.

And yet, there are fragments of philosophy discovered which are not zoötheistic, physitheistic, nor psychotheistic. What are they? We find running through all three stages of higher philosophy that phenomena are sometimes explained by regarding them as the acts of persons who do not belong to any of the classes of gods found in the higher stages. We find fragments of philosophy everywhere which seem to assume that all inanimate nature is animate: that mountains

and hills, and rivers and springs, that trees and grasses, that stones, and all fragments of things are endowed with life and with will, and act for a purpose. These fragments of philosophy lead to the discovery of hecastotheism. Philology also leads us back to that state when the animate and the inanimate were confounded, for the holophrastic roots into which words are finally resolved show us that all inanimate things were represented in language as actors. Such is the evidence on which we predicate the existence of hecastotheism as a veritable stage of philosophy. Unlike the three higher stages, it has no people extant on the face of the globe, known to be in this stage of culture. The philosophies of many of the lowest tribes of mankind are yet unknown, and hecastotheism may be discovered; but at the present time we are not warranted in saying that any tribe entertains this philosophy as its highest wisdom.

[*To be continued.*]

A HOME-MADE SPECTROSCOPE.

By JAMES J. FURNISS.

THE person to whom the study of spectroscopy is really attractive and congenial will not rest satisfied with mere reading, but, sooner or later, will experience a desire to possess a spectroscope of his own—to see for himself the phenomena which are described in the books. He who possesses and can spare the requisite means, will naturally provide himself with an instrument from the optician; but there are no doubt many who, while taking a great interest in this and kindred subjects, are so circumstanced that their outlay for scientific purposes must be limited to a very small sum. It is hoped that this article may be of some service to readers whose fortune places them in the latter category. I do not intend to say anything concerning the principles of spectrum analysis, or the construction and use of spectroscopes in general; that part of the subject may be studied in such treatises as "The Spectroscope and its Applications," by J. Norman Lockyer, or "The Spectroscope and its Work," by Richard A. Proctor, as well as in the more advanced works by Lockyer, Roscoe, and Schellen. I simply propose to give a few hints (which the works mentioned do not give), to enable the beginner, though he may possess little or no mechanical ingenuity, to construct at small expense an instrument which will prove a useful adjunct to his studies.

The chief quality to be desired is usefulness; the appearance of the instrument counts for little: if its performance be satisfactory, that is all that is necessary. The essential parts of the spectroscope are, (1)

the prism, (2) the collimator, (3) the telescope, and (4) the stand. The prism is the most important part of the instrument, and also the most expensive; but, as so much depends upon the performance of the prism, a good one obtained at the first will prevent the disappointment which inevitably follows the attempt to use a cheaper and less perfect article.

A hollow prism filled with a liquid such as oil of cassia, or bisulphide of carbon, may be used, or a flint-glass prism, or one of crown glass. A crown-glass prism may be procured for a comparatively small sum, but its dispersion is small, and to obtain really satisfactory results a train of three or more prisms is necessary, and such a number would be difficult for the beginner to handle without the automatic arrangement to be found in the regular instruments. The price of the hollow prism is a little higher than that of the crown-glass prism, but not quite so high as the price of one of flint glass; of its performance I know nothing by experience, but Lockyer does not speak very favorably of it. Perhaps on the whole the most satisfactory, and consequently in the end the cheapest article, is the flint-glass prism.

The collimator is a tube carrying at its outer end the slit, and at the end next the prism the collimating lens. The tube should consist of two pieces, one sliding easily within the other; so that the distance of the slit from the lens may be regulated. That distance should be equal to the focal length of the lens, in order that the rays of light passing through the slit in diverging pencils may be rendered parallel and sent through the prism as a cylindrical beam. Fig. 1 shows the collimator—*A* being the position of the slit, and *B* the position of the lens.

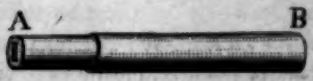


Fig. 1.

The focal length of the lens may be obtained near enough to give the approximate length of the collimator tube by projecting the image of some distant object sharply and distinctly on a screen, and then measuring the distance between the screen and lens. After the instrument is completed the adjustment of the lens and slit with regard to each other may be perfected by the following operation: Remove the prism, and bring the telescope, which must previously have been focused for distant objects, into line with the collimator; then move the sliding tube carrying the slit in or out until the image of the slit is seen sharply defined in the field of view of the telescope. The distance then between the slit and lens is equal to the focal length of the lens. The diameter of the lens need not be quite equal to the width of the refracting face of the prism. An ordinary convex lens of eight or ten inches focus, which may be purchased for a small sum, and which may easily be set in the tube by the student himself, will answer his purpose as well as a much more expensive article.

The figure of the slit is of great importance, and for fine work a

finished piece of mechanism with adjusting screw, etc., is necessary; but the beginner may content himself with an arrangement of much humbler pretensions. I have used a small plate of silver in which an opening (about three eighths of an inch long and one twentieth of an inch wide) had been cut, the width of the opening being reducible at pleasure by means of a little door or shutter sliding smoothly in grooves, and each opposing edge being faced with a strip of watch-spring. Fitted closely into the end of the tube is a piece of cork or wood having in its center a hole larger than the aperture in the slit plate; over this hole the slit plate is fastened, care being taken to stop up any accidental holes or crevices in the cork (or wood, as the case may be), in order to prevent the entry of extraneous light into the tube.

Primitive as this contrivance may appear, I have seen by its means, when using two flint-glass prisms, the *D* line of sodium double, and beautifully distinct. A slit, such as I have described, need not cost more than one tenth of the price charged for a slit by the optician.

Fig. 2 shows a slit of this kind open. *B* is the sliding shutter, and *A* is a piece soldered on the slit plate to bring the surface up level with *B*.

Fig. 2.

Concerning the observing telescope, perhaps Proctor's remarks about a finder for an astronomical telescope may be repeated: "It will be easy for the student to construct one for himself, and will be a useful exercise in optics." But in case the student may not want to take the trouble, he will be glad to remember that an ordinary pocket telescope or spy-glass may be purchased ready made for a dollar or two, and by removing the erecting lenses a small astronomical telescope may be produced which, as the magnifying power required is small, will answer every purpose of the beginner.

The stand may be made in a variety of styles, from the unpretending box on legs, with holes in the sides for the collimator and telescope, to the highly finished tripod of the most aristocratic-looking instrument. The following is one way of making a cheap and at the same time serviceable stand: Procure two disks of seasoned walnut or mahogany or any other hard wood, one about a foot in diameter by three eighths of an inch in thickness, and the other six inches by one quarter of an inch; also get two strips of wood about eight inches long and an inch and a half wide.

Make the larger disk into a table by screwing on three feet—metal hooks such as are used for hanging up clothes make excellent feet; then make a hole in the center of the large disk, and a corresponding hole in one end of each of the strips. Pass a screw downward through the two strips and through the hole in the disk, and let there be a thumb-nut on the screw so that it may be tightened underneath.

Fasten the lower strip of the two permanently to the disk, leaving the other strip free to move in an horizontal plane about the center of the disk. You will then have a stand like that represented in Fig. 3,

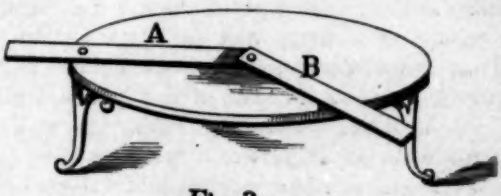


Fig. 3.

A being the stationary arm, and *B* the movable arm. Make the small disk of wood also into a table (see Fig. 4) by fastening in three sharp feet—screws will do. Place this smaller table centrally on the larger one, and it becomes the platform on which the prism is to stand. The next thing is to put the collimator and telescope in their places. For this purpose two small oblong blocks of wood are needed, each one having the upper part hollowed out into a groove to take—one the collimator, the other the telescope. (See Fig. 5, *d*, *d*.) The block carrying the collimator is placed on the stationary arm, and the one with the telescope on the arm which is free to move. Both are secured in their places by elastic bands. The blocks of wood must necessarily be of such a height that the axis of their respective tubes (collimator and telescope) may be brought into alignment (1) with

Fig. 4.

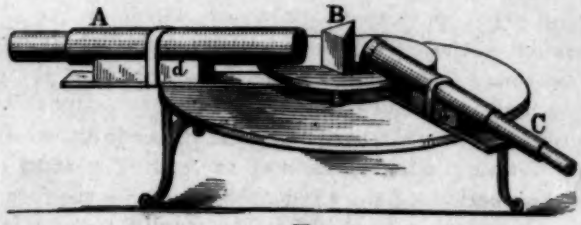


Fig. 5.

each other, and (2) with the prism. The instrument is then complete (see Fig. 5), where *A* is the collimator, *B* the prism, and *C* the telescope.

The manner of using the spectroscope has been described in such works as those I have already mentioned, and does not properly belong to an article such as this, but perhaps a few hints as to the adjustment of the instrument may not come amiss to the beginner. The

angular position of the prism, with regard to the collimator, is a matter of importance, the distinctness and purity of the spectrum depending in a great measure on that position. Perhaps as good a way as any is to find by actual trial the angular position of the prism which gives the best results, thus: Focus the telescope for distant vision, align the telescope with the collimator, and move the slit till it (the slit) is seen distinctly in the telescope; then put the prism in place approximately, and move it round its axis until a position is found where (supposing the light of the sun or diffused daylight to be under examination) the lines in the green part of the spectrum are seen at their best advantage. It must be remembered that a slight change of focus is necessary for every color. When the bounding edges of the ribbon of variegated light which forms the spectrum are seen sharply defined at the same time that the lines across the spectrum are distinct, the adjustment is pretty correct; when such is not the case, the slit and lens are not in their proper relative positions. The narrower the slit, consistent with the necessary supply of light, the finer and more distinct are the lines. A black cloth, or a pasteboard box, with suitable apertures for the collimator and telescope tubes, should be placed over the prism to shut out all extraneous light. In conclusion, I must remark that I do not pretend to describe an instrument capable of doing exact or delicate work. My aim is simply to show with how little trouble or ingenuity a spectroscope may be put together which will help materially those students who wish to obtain a good general idea of a branch of science which has done more to unravel the mysteries of nature than any other inquiry with which the human mind has ever been occupied.

THE SOURCE OF MUSCULAR POWER.

By H. P. ARMSBY.

THE question of the source of muscular power is essentially a question concerning transformation of energy. The most characteristic distinction between plants and animals is, that the former appropriate force from outside themselves, from sunlight, and store it up as potential energy in the various complex compounds which they form in; while animals draw their supplies of force entirely from those compounds in which it has been stored up by plants, and from which it is set free again when they are decomposed in the organism.

In a word, the plant converts the actual energy of the sunlight into the potential energy of organic compounds, the animal converts the potential energy of the organic compounds into actual energy, which manifests itself as heat, motion, electricity, etc.; in the plant the spring is coiled up, in the animal it uncoils, exerting an amount of

energy equivalent to that which coiled it. One of the forms which this energy takes on is that of muscular motion, which we thus trace back to the potential energy of food, and through this to that great source of all energy to our earth, the sun.

We are not, however, satisfied with knowing in this general way that it is the food we eat which serves as a vehicle to convey to us our needful supply of sun-force. We were already acquainted with the necessity for food, but we wish to know which of the ingredients of our food performs this function, or, if all do it, which one performs it to the best advantage.

Until a comparatively recent date it was assumed unhesitatingly that the albuminoids—that is, bodies like albumen (white of egg), fibrine (muscular fiber), caseine (the basis of cheese), etc., which contain the element nitrogen as a characteristic ingredient, and which we shall designate collectively as proteine—were the proximate source of muscular power. It was taught that work was performed by means of an increased oxidation of the fibrine, of which the muscles are largely composed, and that the proteine of the food served to repair the wear thus caused. This view is still found in many especially of the smaller text-books of physiology, and seems to be the one generally current. Even so eminent a physiologist as Professor Austin Flint, Jr., has recently devoted a small book ("The Source of Muscular Power," D. Appleton & Co., 1878) to its defense; but nevertheless it was never founded upon experimental evidence, and has now been rendered untenable in its original form.

Karl Voit, of Munich, was the first to make exact experiments on this subject, and in 1860 he published the results of his researches, which showed conclusively that, contrary to the then generally accepted theory, muscular exertion did not increase in the least the amount of proteine decomposed in the body, although it *was* accompanied by a large increase in the amount of non-nitrogenous matters oxidized. This fact was immediately accepted by many physiologists as a proof that the commonly received view of the source of muscular power was incorrect, and that that power was in reality derived from the non-nitrogenous components of food—its fat, starch, sugar, etc. According to them, the muscles are, like a steam-engine, simply an apparatus for the transmission of energy furnished by some other substance, while the fat, etc., is the fuel of the living machine.

Voit and his followers, on the contrary, still hold that proteine is the proximate source of muscular power, though their views have naturally been materially modified by the experimental results just mentioned.

Voit compares the constant decomposition of proteine which goes on in the body to the constant flow of water in a stream. A mill situated by the stream may use the whole power of the water, a half, a quarter, or any desired fraction, without in the least altering the

amount of water running past. So in the body the decomposition of proteine, which is the source of power to the muscles, goes on constantly, independently of whether the energy which is set free takes the form of motion or appears in some other shape.

These are, in outline, the views of the two schools into which physiologists are divided upon this point. Professor Flint, in his book already referred to, advocates, and seeks to sustain by experimental evidence, a theory which may fairly be said to have been abandoned by both sides; and a review of his book, which appeared in this journal in April, 1878, having given some prominence to the subject, a brief review of the present state of our knowledge upon it may not be uninteresting.

It will facilitate an intelligent comprehension of the matter to preface our study of the main question with some explanation of the means by which our knowledge of the amount of nitrogenous and non-nitrogenous matter decomposed in the body is gained, and by some considerations regarding the effect of the kind and quantity of food upon the nutrition of the muscular system and the excretion of nitrogen.

The animal body may for our present purpose be regarded as consisting, besides water, of proteine and non-nitrogenous matter, chiefly fat: the latter contains the elements carbon, hydrogen, and oxygen; the former, in addition to these three, nitrogen. Both classes of matter are gradually oxidized in the body, and are finally converted into carbonic acid, water, and urea, the former of which is excreted through the lungs and skin, the latter through the kidneys, and the water partly by all three channels.

In the urea (together with small amounts of uric acid and other products) is contained the nitrogen resulting from the oxidization of the proteine.

It has been established, by an overwhelming mass of evidence, that all the nitrogen which leaves the system does so in the urine, and that the amount of this element in the latter is an accurate measure of the amount of proteine destroyed in the body. A determination of ureal nitrogen thus informs us of the amount of albuminoids oxidized; while a determination of the amount of carbon excreted in carbonic acid and urea, taken together, enables us, by a little calculation, to find the amount of fat oxidized.

By means of experiments conducted on this basis a tolerably full knowledge has been obtained of the effect of food upon the formation of flesh (muscular substance) and fat, and facts have been discovered which have an important bearing, both on our views of the origin of muscular power and on the precautions necessary in experimenting upon this subject. The earliest workers in this field were Bidder and Schmidt, followed by Karl Voit, in conjunction, first with Bischoff and later with Pettenkofer.

One result of these researches has been to demonstrate that *the consumption of proteine in the body is determined by the amount of it present in the food.* If the food contains but little proteine, but little is oxidized in the body ; if more be added, the consumption of it in the vital processes promptly increases, and within at the most three or four days comes into equilibrium with the supply, or very nearly so.*

Another important point is the distinction, first introduced by Voit, between what he calls circulatory and organized proteine. He has shown, by experiments which it would take too much space to describe, that the proteine of the body exists in two states : first, as organized proteine, which is comparatively stable ; and, second, circulatory proteine, which exists in much smaller amount than the other, and undergoes a much more rapid decomposition in the body. The first effect of albuminoids in the food is to increase the amount of this circulatory proteine and the rapidity of its decomposition, and it is in this way that the consumption of proteine in the body is, as has just been stated, determined by the supply of albuminoids in the food. The production of organized proteine, which Voit supposes to constitute the muscular tissue, is, on the contrary, much less rapid, it being slowly formed from the circulatory proteine under proper conditions.

Some authorities dispute the correctness of the names circulatory and organized proteine, but there is no dispute as to the fact, shown by his experiments, that most of the proteine of the body exists in a comparatively stable form, while a small portion, dependent in amount upon the supply in the food, is being continually and rapidly oxidized and furnishes most of the nitrogen eliminated through the kidneys. We might compare the stock of circulatory albuminoids in the body to a mass of water contained in a vessel with a small aperture in the bottom. If there is no supply, it quickly runs out. If a small stream of water be let in at the top, a small supply of water may be maintained in the vessel. If a larger stream be admitted, the depth of water in the vessel will at once begin to increase, but at the same time the pressure on the bottom, and consequently the rapidity of the outward flow through the aperture, increases, and outflow and inflow soon come into equilibrium. If the supply be diminished, the level of the water sinks till the hydrostatic pressure causes the outflow to again equal the inflow.

Voit's results have been abundantly confirmed by other observers in experiments on various animals, including man, and must be regarded as fully established, whatever view we may take of the interpretation put upon them by their author. In Professor Flint's book, however, we fail to find any reference to these discoveries, though they have, as we shall see, a most important bearing on his own experiments. He does, indeed, mention the similar but less complete results

* Voit's experiments were made on dogs. With herbivorous animals the same law holds, but the change is not so rapid.

of Lehmann (p. 35), and states (p. 41) that "the change of the normal diet to a regimen of non-nitrogenous matters alone of itself diminishes very largely the excretion of nitrogen"; but the more recent results of Voit and others are passed over in silence, though on pages 26–28 he mentions some facts and introduces some considerations which go to show the correctness of these results.

Coming now to the main question, we follow the general order of Professor Flint's book, and consider, first, the effect of muscular exertion upon the metamorphosis of matter in the body as shown by the excretions, and, second, the conclusions which can be drawn from these effects as to the proximate source of muscular power.

According to Professor Flint (p. 40), the experiments of Fick and Wislicenus in 1866 constituted "the starting-point of the new theory of the origin of muscular power." This, however, can hardly be said to be the case, at least as regards the experimental evidence on which that theory is based. We have already stated that Voit was the first to seek for evidence of the truth of the views held by his predecessors, and his experiments, as also those of E. Smith, antedate those of Fick and Wislicenus by some six years. Not only so, but the theory itself had been broached before Fick and Wislicenus made their experiments, as may be seen from their paper on the subject. At the same time their results gave it a powerful impulse and won for it more general attention.

Voit's conclusions have been fully corroborated by numerous and able investigators,* and are at present accepted by the great majority of physiologists; and we naturally expect some reference to them in a critical discussion of this question. We find, however, no mention of them; we are left to infer that the experiments of Fick and Wislicenus are the chief basis for the conclusion that work does not increase the elimination of nitrogen in the urine, and the author enters into a criticism of these experiments which is groundless, since it mistakes entirely their object.

The experiments of Fick and Wislicenus were not designed to show that work did not increase the destruction of proteine in the organism, but that the latent energy of the amount destroyed was insufficient to account for the work done. For this purpose they ascended an Alpine peak of known height, carefully determined the amount of nitrogen excreted during the ascent, and calculated from this the amount of proteine destroyed. Their diet before and during the performance of the work contained no proteine. On reckoning the amount of latent energy contained in the proteine destroyed, as shown by the quantity of heat which it would have yielded if burned, they found this energy

* Among these confirmatory results may be mentioned, as having historical as well as scientific interest, those obtained in 1867 by T. R. Noyes, M. D. ("American Journal of Medical Science," October, 1867), then a student in the Yale Medical School, which in the main agreed with those of Voit.

to be insufficient to raise the weight of their bodies to the height of the mountain, and hence they conclude that the lacking energy at least must have been derived from non-nitrogenous materials.

Their experiments were well designed for the purpose intended, and the criticisms of Professor Flint (pp. 40–43) that the decrease in the excretion of nitrogen during and immediately after the work was due to the abstinence from albuminoid food, and that no comparison of rest with work was made, while doubtless well founded, do not touch the point at issue, viz., that a certain amount of work was performed and a certain amount of proteine destroyed, and that the latter was not, according to their calculations, sufficient to yield the amount of force actually exerted. The only grounds upon which the validity of their results can be successfully disputed are either that the principle of calculation employed by them or their data as to the heat of combustion of proteine were erroneous. We shall return to this point later. It may be added, in regard to the experiments of Voit and the other investigators in this field, that they are free from the failings which Professor Flint finds in those of Fick and Wislicenus, and also of Parkes.

The experiments of Dr. Parkes, which Professor Flint apparently regards as at least partially sustaining the view which he advocates, show in the great majority of cases either no increase or a slight decrease of the excretion of nitrogen as a consequence of work, and Dr. Parkes himself expressly says ("Journal of the Royal Society," vol. xix., p. 349): "The result of both series was, so far, to confirm the experiments, which show that the changes in the nitrogen of the urine . . . are small in extent, and afford no measure of the work."

Professor Flint's chief reliance, however, seems to be the experiments made in 1876 by Dr. Pavy, and published in a series of papers in "The Lancet," and his own experiments made in 1870 ("New York Medical Journal," June, 1871).

These two series of experiments differ decidedly, both in method and results, from those heretofore mentioned, both of them showing, according to their authors, an increased elimination of nitrogen through the kidneys as a result of muscular exertion. They were made upon two pedestrians, Perkins and Weston, during the performance of various feats of pedestrianism, and hence under conditions that excluded an exact measurement of the amount of work performed. Unfortunately, also, they could not, from the nature of the case, be made with that rigorous control of all the conditions of experiment which is essential in such researches; and they suffer under various sources of inaccuracy which materially lessen their value.

In the first place, no attempt was made to regulate the diet of the two men; they ate what and when they chose. In most experiments on this subject it has been considered necessary to employ a perfectly uniform diet as regards nitrogen, and an instructive example of the pains taken to insure it may be found in a paper by Voit and Petten-

kofer in the "Zeitschrift für Biologie" (1866, p. 466). In the case before us, however, the investigators contented themselves with weighing the food eaten and estimating its contents of nitrogen. We have seen that Professor Flint elsewhere insists upon the importance of the food eaten in its effects on the excretion of nitrogen, but, both in his own experiments and Dr. Pavy's, there were, according to their own estimates, great variations in the amount of nitrogen ingested from day to day, as, for example, 65·68 grains and 161·72 grains, or, on another occasion, 522·42 grains and 871·92 grains on two successive days in Dr. Pavy's experiments, and 144·70 grains and 383·04 grains in Professor Flint's.

Such great and sudden variations as these could not but impair the accuracy of the experiments, and cause corresponding fluctuations in the amount of nitrogen excreted, as has been sufficiently shown by the investigations of Voit and others already alluded to, and the results bear testimony that such was the case.

Furthermore, not only did the quantity of nitrogen ingested from day to day vary, but even these varying amounts were not accurately determined by analysis, but simply, with a few unimportant exceptions, estimated from the average composition of similar articles as given by Payen. Neither Dr. Pavy nor Professor Flint appears to have even taken the trouble to estimate the water of the various articles of food, but to have simply weighed them in the fresh state—a fact which alone deprives the results of all claim to strict accuracy, since the water content of such articles as fresh meat or bread, for example, is quite variable, and the proportion of nitrogen in the fresh substance of course varies correspondingly. While such a method may give an approximation to the truth, it is impossible that, when applied to such a varied diet as that taken in these experiments, it should give results of scientific exactness.

The estimations of the ureal nitrogen appear to have been made after approved methods, and are to be assumed to be correct; but, even if we assume the accuracy of the estimates of nitrogen in the food as well, the results of Dr. Pavy do not show what he claims for them. They do, indeed, show that there was an increase in the average daily excretion of nitrogen during work over that during rest of 194·12 grains, and, at the same time, an increase of 201·63 grains in the average amount of nitrogen daily ingested. The only conclusion which can be drawn from these figures is, that during work more nitrogen was excreted *because more was taken in the food.* That muscular exertion caused any increase in the excretion of nitrogen we have no evidence.

With Professor Flint's experiments the case is somewhat different. There the amount of proteine taken in the food was considerably less during work than during rest, while the excretion of nitrogen remained about the same, so that the *relative* excretion was increased.

This, Professor Flint claims, shows that the work performed was accomplished at the expense of muscular tissue, which was destroyed and caused the increase in the relative excretion.

Were the data as to food more exact, this might be the case; but, as it is, the result seems to need further confirmation before it can be accepted.

The only other similar result, so far as we know, is one recently obtained by E. von Wolff in experiments on the horse; but, having access only to a brief abstract, we are unable to judge of the accuracy of the work, though from the high reputation of this investigator it is to be assumed that it was executed with every precaution. It was found that an increase of the work performed was accompanied by an increased excretion of nitrogen in the urine; but the author reserves the details of his experiments till further observations shall have confirmed or disproved their results, and at present, until the subject has been more thoroughly investigated, we must follow the preponderance of evidence, which is most decidedly in favor of Voit's result, viz., that work does not increase the destruction of proteine in the body and the consequent excretion of nitrogen through the kidneys.

Thus far we have simply been considering experimental results, without regard to the conclusions to be drawn from them; we now come to their interpretation, and here it must be admitted, at the outset, that the data now at command are not sufficient to enable us to solve the problem of the source of muscular power. But, though we do not know precisely what the proximate source of muscular power is, we are able to indicate with tolerable certainty the direction in which an answer to this question is to be sought, and to say that certain conclusions have a high degree of probability.

It would seem at first thought that if, during work, the oxidation of non-nitrogenous matters in the body increases, while no more proteine is destroyed than during rest, the non-nitrogenous matters must be the source of the power exerted. This appears to be Professor Flint's view, as indicated by several passages in his book; but, though it may be a *probable* conclusion, it is by no means a *necessary* one. We have already mentioned the fact that Voit and his followers still consider the constant decomposition of circulatory proteine which goes on in the body to be the source of muscular power, comparing it to a constantly flowing stream, the energy of which may be converted at will into motion, or be allowed to take the form of heat; and there is nothing in the experimental results above adduced to forbid this interpretation.

It has been shown by Voit and Pettenkofer to be at least very probable that proteine in its decomposition in the body takes up the elements of water and splits up into urea and *fat;* and it is easy to show by calculation that 100 parts of proteine could produce in this way 51·4 parts of fat. This process, now, takes place during rest, and it is quite con-

ceivable that during work the proteine is decomposed completely into carbonic acid, water, and urea, and that thus the latent energy which would otherwise be stored up in the fat is applied to the production of motion. If this were shown to be the case (and it seems not improbable that something similar to it actually takes place), it would become largely a question of nomenclature whether we should regard the proteine or the fat which is formed from it as the source of muscular power. For ourselves, we believe that the truth will eventually be found to lie between the two extreme views now advocated, and that muscular force will prove to have some such origin as that above indicated.

At the same time there are certain facts immediately to be considered which show that the process is by no means so simple as that just sketched.

If we turn from the study of the effects of muscular exertion to that of its conditions, we shall get much new light, and be helped to a more rational judgment of the theories as to its source. Presupposing the existence of a healthy and well-developed organism, we may specify *four* conditions as, from our point of view, the most important:

1. The facts of common experience appear to show unmistakably that a liberal supply of proteine in the food is one of the conditions of any sustained muscular exertion. This, however, does not necessitate the conclusion that the proteine is the source of the power exerted: its decomposition, as we have seen, goes on independently of muscular exertion, and may be regarded as simply one of the conditions of the healthy activity of the muscles.

2. The largely increased excretion of carbonic acid and water during work indicates a necessity for a liberal supply also of the non-nitrogenous constituents of food. At need, however, this demand may be supplied by the albuminoids of the latter, or perhaps by fat already formed in the body.

3. An essential condition of continued activity of the muscles is the constant removal from them by the circulation of the chemical products of their action. Certain of these products, notably lactic acid and acid potassium phosphate, if allowed to accumulate in the muscle, produce the sensation of weariness, and shortly incapacitate it for further action. If they be removed, either by the blood or by injection of a weak salt solution, the muscle is again capable of work; while, if they be injected into a fresh muscle, they produce the same effect as if naturally formed there. The same or similar processes go on in the muscle after death, and the *rigor mortis* is caused by the solidification of the jelly-like *myosin*, which is also one of the products of the action.

4. A most important condition of muscular activity is found in the capacity which the body has to store up oxygen in itself during sleep, to be used later in the waking hours. This capacity was discovered by Voit and Pettenkofer in experiments on men, and has been con-

firmed by Henneberg's experiments on oxen. More carbonic acid is excreted by day than by night, since more work is then done. But at the same time *less* oxygen is taken into the body in the daytime than during the night. For example, in one of Voit and Pettenkofer's experiments, for every 100 parts of oxygen which entered the system in the daytime 175 parts were contained in the carbonic acid excreted, while in the night the same relation was expressed by the number 58. When work was performed the difference was still greater. This and similar experiments show plainly that a large part of the carbonic acid excreted is formed at the cost of oxygen previously laid up in reserve, and that the increased rapidity of respiration during work is not for the purpose of supplying more oxygen, but of removing the carbonic acid.

It has been also shown that the amount of oxygen that can thus be stored up in health is proportioned to the amount of albuminoids in the food, and this is another indication of the importance of these bodies in the production of muscular power.

The necessity of this storing up of oxygen is strikingly shown by experiments on two diseases in which the patient is almost incapable of muscular exertion, viz., diabetes mellitus and leukæmia lienalis. In these diseases the total excretion and the total amount of food are not much different from those in health; but there is no such storing up of oxygen as in the healthy organism, and there is also an almost entire lack of strength.

This fourth condition is, for our present purpose, the most interesting and important of all. It shows that work is not produced by the direct oxidation of food materials by the oxygen of the blood, but that the muscles themselves contain a store of latent energy which the will can set free at pleasure, independently of oxygen, while the blood serves to wash out the waste products and gradually to renew the supply of force during those periods of rest of which this fact explains the necessity.

That the seat of this latent energy is in the muscles is shown by the fact that they are capable of contraction for a time after their blood-supply has been cut off, or even after their removal from the body. A frog's heart, when removed from the body and freed from all blood by injection of a weak solution of salt, will continue to beat for hours, and the whole animal under the same circumstances moves, leaps, and behaves in short like a living animal. Agassiz relates that on one occasion he captured a shark which fought as long and fiercely as is usual with these animals, but which, when finally secured, was found to have its gills eaten through by parasites, and almost all its blood replaced by sea-water. (Liebig.)

Like a bent spring the muscle contains a certain amount of potential energy, which the will can use at pleasure; but when the supply is once exhausted, when the spring has lost its tension, a further supply of force from without is necessary before more work can be performed.

These facts furnish an important clew to the source of muscular power. The experiments of Voit and Pettenkofer show that while storing up oxygen during rest the organism is laying up a store of force to be used later; while those of Henneberg connect this storing up of oxygen with the supply of albuminoids in the food, and render it highly probable that it is accomplished by their means.

Two hypotheses as to the function of the albuminoids as agents in the production of muscular power at once suggest themselves. The first is, that they simply serve as reservoirs of oxygen, which latter is used at will to burn the non-nitrogenous parts of the food, the result being work, heat, and an increased excretion of carbonic acid and water. This would be the view of those who consider the carbhydrates and fats as the source of muscular power, and its simplicity renders it attractive. It must be noted, however, that it requires us to look upon the non-nitrogenous materials oxidized as part of the muscle, since the latter can perform work independently of the circulation of blood through it.

A second hypothesis, however, less simple and easily grasped than the first, is considered by many high authorities to accord more closely with the facts of the case and with our general conceptions of vital activity.

This hypothesis supposes that during rest some of the substances of the muscle-cells decompose into simpler compounds, and in so doing set free their latent energy, which energy, instead of appearing as heat, etc., is used to build up out of other constituents of the cell a still more complex compound containing more potential energy than its components, just as one portion of society may acquire wealth at the expense of another portion, with no increase of the total wealth of the community.

The substances which are thus "synthesized" are proteine, an unknown non-nitrogenous matter from the blood and oxygen; the hypothetical compound thus formed accumulates to a certain extent in the muscle, and, when the latter is called on to perform work, splits up, yielding carbonic acid, water, and other non-nitrogenous matters, and proteine or some similar compound, and giving forth the amount of force which was required to form it. The non-nitrogenous substances which are formed are supposed to be rapidly excreted; while the nitrogenous product, instead of undergoing further decomposition, is used over again to re-form the hypothetical substance.

This view has much in its favor. Various syntheses like that above outlined are known to take place in the body; and, moreover, all the facts seem to indicate that muscular force originates in a splitting up of some substance in the muscle, accompanied by the liberation of force, rather than by any process of oxidation in the ordinary sense of the word.

The hypothesis explains the object of the storing up of oxygen in

the body during rest, and its connection with the laying up of a reserve of force: the oxygen enters into the supposed complex compound much as the nitric-acid radicle enters into nitro-glycerine or gun-cotton—it is held in a state of unstable equilibrium, ready to enter into new and simpler relations with its neighboring atoms, and to set free the force by which it was placed in its unstable position. The hypothesis explains also that necessity for albuminoids in the food of the laboring animal which practical experience has shown to exist, as well as the fact that there is no greater excretion of nitrogen during work than during rest; the proteine serves as the basis for the alternate synthesis and analysis which constitute what might be called the atomic mechanism of muscular activity without itself being destroyed. Furthermore, it shows why we need rest after work; in the first place, the circulation must have an opportunity to remove those waste products which accumulate in the working muscle faster than they can be carried off, and in the second place a fresh supply of force must be stored up in the way described before it is ready to be used at the command of the will.

Thus this theory explains all the facts now known, and, while it is but an hypothesis, it is still based on the "scientific use of the imagination," and indicates the direction in which we may confidently look for an advance of positive knowledge.

If it be true, much of the current discussion upon the source of muscular power is but a "strife of tongues"; both proteine and non-nitrogenous substance are necessary, and an inquiry as to which is the source of the power would resemble an inquiry as to whether the explosive force of nitro-glycerine was derived from the glycerine or the nitric acid used in its manufacture, and would be a question of metaphysics rather than of natural science.

It might be asked, since this is a question of transformation of energy, why we do not apply the law of the conservation of energy, and from the heat of combustion of the various elements of food calculate their value as reservoirs of force by Joule's formula. This has been frequently attempted, notably by Fick and Wislicenus in their experiments already alluded to. These investigators showed that the amount of force contained in the proteine which was destroyed in their bodies during the ascent of the Faulhorn was insufficient, if wholly converted into motion, to raise their bodies to the height of the mountain.

Various other attempts at the same sort of calculation have been made, with more or less of care and insight: we may mention here those of Dr. Pavy, which rest on several assumptions of questionable accuracy; and those of Professor Flint, made upon the same plan, with the object of showing the worthlessness of Dr. Pavy's—an object which he has doubtless attained.

It would carry us too far to discuss here the value of these results,

and we must content ourselves with two general statements: 1. The heats of combustion of the various food-substances, which serve as the foundation of all such calculations, have not yet been determined with sufficient accuracy to render those calculations demonstrative. 2. Even if it were shown that the results of Fick and Wislicenus are correct, and that the albuminoids destroyed during work are not sufficient to supply all the force exerted, this in no way invalidates our hypothesis, since the latter does not place the source of muscular power in the albuminoids alone, but in the joint action of these and of non-nitrogenous matters.

It will be seen that the foregoing views as to the origin of muscular power are in some respects in substantial accordance with those of Professor Flint. Like him we hold that the source of muscular power is to be sought in the muscles themselves, and not in any burning of the constituents of the food in the blood or the juices of the body. Muscular power, we believe, does not have its immediate origin in oxidation but in the splitting up of an unstable compound into simpler ones.

We differ from him, however, both in regard to the effect of muscular activity upon the destruction of proteine in the body and in regard to the conclusions to be drawn from these effects. Professor Flint claims that work increases the amount of proteine destroyed; we believe we have shown that neither his own experiments nor those of Dr. Pavy are sufficient to prove this, and that the preponderance of evidence is altogether in the other direction.

He says further (p. 31): "In other words, is the muscular substance an apparatus for transforming the force locked up in food into power, or are the muscles themselves consumed, the elements of food being used for their repair? These questions may be resolved by little more than a single experimental line of inquiry: Does physiological exercise of the muscular system increase the elimination of nitrogenized excrementitious principles?"

Were these questions capable of being resolved in this simple manner, their answer would be just the reverse of that which Professor Flint gives to them; but we have already seen that such researches are entirely inadequate, of themselves, to settle the matter, and that very different considerations must be attended to in order to attain that end.

Some of these considerations we have endeavored to present, as clearly as might be, in the foregoing pages, while pointing out what seems to us the false method by which Professor Flint, in his very interesting book, has sought to maintain a conclusion which itself is doubtless correct, viz., that muscular power originates in vital actions taking place in the cells of the muscles themselves and not in a simple oxidation of food-constituents. We can not but regret that this fact, which he so clearly appreciates and states, should be supported

by invalid reasoning, and that the sanction of a name so eminent among American physiologists should be given to views which do not accord with the results of the best and most recent investigations on this subject.

THE RESULTS OF ABSTRACTION IN SCIENCE.

By CHARLES T. HAVILAND.

THE old scholastic controversy as to the reality of universals has its analogue in modern times. Formerly the strife had its religious implications, and it was from the arsenal of theology that the defenders of realism procured their weapons. Theological realism has now been virtually abandoned, and it is to metaphysics that the realists appeal to defend their abstractions from the searching analysis to which scientific modes of thought would most assuredly subject them.

Realism was the doctrine that universals have a real existence, entirely independent of the concretes from which they were generalized. It was held, for instance, by the older realists, that there is in the universe a perfect circle, freed from the imperfections of those we are able to construct; that this is not an idea generalized from the circles we see; that it is not the result of abstracting the imperfections that are inseparable from any circle we can draw and confining our attention alone to its perfections; but that there really exists an archetype of which circles as we know them are merely imperfect reproductions. This doctrine, even among the scholastics, found its strong opponents, and in its cruder forms was obliged to succumb. In metaphysics, however, realism, in a more refined form, found a soil fitted to its luxuriant growth, and the belief in entities and quiddities, and the other metaphysical essences associated with these, spread to such an extent that the successive influences of men as powerful as Locke and Hume sufficed to check rather than to exterminate it. The scientific tendency of thought, in which these men were pioneers, is now making havoc among the heirlooms of a past civilization. This tendency, which accepts nothing on mere assertion, and which forces every belief to produce its credentials, is now bringing its methods to bear upon the entities of metaphysics, and proving conclusively that they are of no nobler descent than the phenomena in which they originated.

The decadence of realism affords so striking an example of the general change in the conception of nature that has taken place within the past three centuries as, to a certain extent, to justify Comte's generalization as to the natural development of thought. There could, historically, hardly be a better example of this change than in the con-

sideration of the decline of the theological and metaphysical conceptions of nature and the abstractions that grow out of them.

All the recent advances in ethnology teach us that man, as far back as we can trace his beliefs, explained the universe by the only power that he knew—that which he was himself conscious of possessing. To him every manifestation of power was the act of some god or demon who inhabited the sun, the moon, the forests, or the waters, and whose vengeance (for the primitive man's faith in diabolical agencies might well shame the believers in the more sublimated theories in regard to that cheerful dogma at the present day) it was necessary to placate by offerings, by sacrifices, by penances, and by supplications. No adequate test of reality then existed, and the spirit of a dream was as truly materialized as anything that could not be subjected to those most "realizing" of all senses—touch and muscular power.

The whole history of fetiches, idolatry, and polytheistic religions generally shows how strong was the belief in the immanence of powers beyond the human. An increase of culture served to remove the home of the gods to more distant fields, and, as man learned to philosophize, metaphysics gradually encroached on theology. The ideas of Plato, which to him were as real as the fetiches to the savages, were, as abstractions, the metaphysical substitutes for the demons that had preceded them.

The contest of nominalism with realism, which, during the middle ages, waxed so hard, paved the way for the scientific—or, in the Comtean terminology, the positive—conception of nature. Discerning in a great class of phenomena the evident progress of thought, Comte was led to suggest his famous law. As certainly as it has been disproved as a general law that thought passes from the theological, through the metaphysical, to the positive stage, so certainly has this theory a sort of broad suggestiveness, which often leads to otherwise undiscovered truths. The odium naturally and justly attaching to Comte's later social theories has had the tendency to obscure the value of his philosophical speculations. It is a fault (if it be a fault) of all founders of systems to over-estimate the application of their theories. Impressed by the discovery of a new truth, what wonder if they group all things under their rubric, and leave to their followers the task of clearly defining its application? Although in his constructive theories Comte erred most fatally, yet the fertility of his suggestions gave a great impetus to a more scientific philosophy, and extended its bounds over hitherto untrodden fields. Many owe to him much more than they willingly admit—more than they themselves are conscious of; and his uncompromising nominalism has had the tendency more precisely to define the meaning of abstract terms, and clear philosophy, and through it science, of much metaphysical verbiage.

While thus scientific nominalism is clearly in the ascendancy, there is a certain phase of realism which enters so completely into many

scientific discussions, and has such a broad bearing upon their decision, that it may well claim our attention.

Abstraction is necessary to all knowledge. As soon as we advance at all beyond the knowledge of concretes—as soon even as we begin to compare one thing with another, and note their resemblances and differences—so soon we commence the process of abstraction and generalization. This mental act is not only the foundation of all conscious classification, but it is itself the infancy of consciousness. The earliest perception of resemblance in two objects which, next to the perception of difference, is the lowest term to which consciousness can be reduced, and which probably appeared contemporaneously with organized matter, was the result of incipient abstraction. The likeness of two things not identical, but resembling each other in many respects, would be perceived by any being possessed of the least consciousness. As the differences increase and the resemblances decrease in number, it is only by a thinking away from (abstracting) the differences and confining the attention to the resemblances, that classification commences.

One of the greatest difficulties in dealing with the early growth of consciousness is the lack of terms applicable to it. Man commences to philosophize only when he is far advanced in culture, and the terms he then uses are ill fitted to express the mental acts of men far below him in intelligence, and in a still greater degree of those lowest orders of animals in whom consciousness first appears. However ill they may express our meaning, we are confined to the words we have, and they must be accepted as indicating but in a slight degree the mental process going on in the early organisms. When we speak of the abstraction necessary to the perception of resemblance, it is of course to be understood that the process is but slightly analogous to the classification of the scientist; still, fundamentally it is the same. For long ages before man appeared upon the earth this unthinking classification was going on. A brain was gradually being developed which had impressed upon it the experiences of its myriad ancestors, and which furnished to the primitive man an instrument of thought enabling him to adapt himself to surrounding conditions with far more success than his less favored compeers. The æons during which man struggled with the forces of nature, all the while gaining slight increments of experience and knowledge of nature's laws which he transmitted to his descendants, were necessary to the production of the Greek philosopher who, from his highly specialized mind, could evolve a theory of the universe. Ignorant of the vast ancestry of human experience, it is no wonder that men should have been ready to accept any but the true explanation of our belief in the laws of nature, and should have been unable to discern any relationship between those laws which to them appeared necessary and immutable and those newly discovered laws or sequences which they believed might be easily set aside.

Viewed in the light of evolution, a law of nature is merely the most generalized expression for a particular occurrence of phenomena. Take, for instance, the law of the conservation of energy: observation, long continued, shows that with whatsoever objects we deal, and however we may apparently destroy the energy contained in them, yet closer observation, with more accurate instruments, will discern that the energy previously visible has only disappeared to reappear in another form. Finding the same result in every case to which we are able to apply our tests, and discovering no exception to the rule, we abstract the particular objects we have been considering, and, confining our attention to the persistence of energy which each displays, group this class of phenomena into one category and express the likeness by the law that energy endures.

Each deduction from a law is a separate verification of its truth, and as these verifications increase in number the probability of finding an exception decreases. Hence, the law soon assumes a form of necessity as different as possible from its original character. Add to this that many of the laws of nature have only to be expressed to be admitted —laws whose concretes were objects of observation to our earliest ancestors away back in the youth of life upon our globe, and are, to us at least, intuitive—and we see how natural the attribution of necessity to them appears. Besides this, the word law conveys a meaning entirely outside its scientific acceptation. As popularly used it expresses the command of a ruler; and this civil or theological meaning, as applied to the laws of nature, is continually being brought to scientific discussions, much to the detriment of their clearness. Mathematics alone among the sciences has been able to keep clear of these dangerous alliances, and we there still see the word used in its properly scientific application as an order of sequence merely. Although mathematical law is not coextensive with physical law, it is this meaning which we should endeavor to preserve. The word is an unfortunate one at best, and some philosophers and scientists have advocated its disuse and the substitution of some more accurate term; but it is too deeply rooted in scientific language for that, and we can only enter a protest against its use in scientific discussions in other than a scientific sense. We have only to consider the scientific genesis of the term to obtain a rule for its application. Considered merely as the generalized expression of the result of observation, we clearly perceive that, however long these observations may have continued, they carry with them no necessity except in so far as relates to our own organism. It is just here that the idea of necessity asserts its power. Take the most fundamental law of mechanics, or even (for the supposed necessity in each case arises in the same way) one of the primary axioms of mathematics, and, by an analysis of the genesis of these conceptions, we shall, with the aid of the light that the theory of evolution sheds into those obscure recesses of the mind where consciousness is coming into

being, be enabled to perceive there the process of the growth of this mental necessity in direct correspondence with the evolution of the organism. Through untold ages have the ancestors of man beheld numberless objects break into parts, no one of which was ever as large as the original whole. Through vast geological ages have these facts been impressed upon an evolving mind which, as it never perceived the contrary, had not the data upon which even to imagine it. With this immense induction behind him no wonder, man, when he was able to speculate, asserted the necessary truth of the axiom that "the whole is greater than any of its parts." A necessity for a particular order in nature we know nothing of; that conception arises from the growth of the organism in correspondence with nature as it is.

The old metaphysical conception of types has perhaps had as much influence on scientific controversy as any abstract term. Alike with species, useful when regarded purely as an abstraction from concretes and as an hypothetical form about which to group different individuals, when regarded as a reality it may prove, even in the hands of an able scientist, an *ignis fatuus*, luring him from the solid ground of scientific knowledge into the quagmires of metaphysical speculation. Like all abstractions, when sufficiently limited in their application, they may lead to useful results, and may suggest resemblances that might otherwise escape the observer. Thus to the conception of types was Goethe indebted for the valuable suggestion he gave to biology. Although these realistic conceptions of abstraction have sometimes brought forth valuable scientific hypotheses, yet their effect commonly has been the reverse. Like the doctrine of final causes, which is popularly supposed to have suggested to Harvey the circulation of the blood, by opening the question as to the use of the valves in the veins, so the doctrine of the existence of types has sometimes been productive of good results; but, as the doctrine of final causes, whatever may be its theological truth, is utterly extra-scientific, and has consequently been a steady opponent of any advance beyond present knowledge, so the theory of types has proved one of the strongest enemies to the acceptance of the theory of evolution. It was his metaphysical belief in this conception that was avowedly the basis of Agassiz's opposition to evolution. Types and species were to him real existences, to which phenomenal existence corresponded. There existed in the universe, for instance, an archetypal form on which vertebrates were modeled. Genera and species corresponded with these types in a greater or less degree, and the assumption that varieties were incipient species which, by successive modifications, could grow into "good species," was, in his view, the introduction of complications into biology sufficient to destroy all classification. Looked at from this standpoint, his vast biological knowledge only served to furnish him with stronger weapons in defense of his position. It may well be doubted whether any proof, however strong, would have been suffi-

cient to have changed his opinion; for metaphysical conceptions, like spiritual substances, yield to no carnal weapons.

Herein consists the great danger in the introduction of abstractions into scientific discussions. Let them once be assumed to have an existence outside the concretes from which they are formed—and the tendency with many is to consider them in this light—and no argument, based upon the observation of phenomena, is sufficient to overthrow them. It can not be too strongly impressed upon the minds of all that science has nothing to do with such conceptions. As science consists in the observation of phenomena and the deduction of the laws of their orderly occurrence, and as scientific hypothesis consists in the prediction of the order of the future occurrence of phenomena and the linking together of diverse phenomena under an assumed order, we see that there is no place where these realistic conceptions can enter. Their sphere, if anywhere, is in metaphysics and theology. Scientists should exercise the utmost care not to misapprehend their own terms, and should then compel acquiescence in the meaning they give to them. Looseness in the use of words is one cause of the indefiniteness that pervades the controversy between the scientists and the theologians.

Force, cause, matter, and science itself are abstract terms, and when analyzed into their concretes will assume a meaning very different from that often given them. All that we scientifically know of force is, that it connotes the presence of motion (i. e., things moving) under different conditions. These we separate into actual and potential motion, and the cause of the motion into actual and potential force or energy. Here the necessity of the use of these abstract terms is at once apparent, as we can scarcely make an assertion without employing them. Cause, as in the above-mentioned case of law, is simply the preceding conditions of any phenomenon, and in the absence of which, as far as we know, it can not occur. Likewise matter, the most "real" of all abstractions, is, scientifically speaking, merely the symbol of a congeries of the phenomena of extension; and Professor Tyndall was speaking entirely within scientific bounds when he said he discerned in it the promise and potency of all forms of life. This did not in the least prejudice the materialistic-idealistic controversy as to its ultimate constitution. In his case he had repeatedly distinctly avowed his non-acceptance of metaphysical materialism, and in a few concise sentences had adduced a stronger argument against that belief than can easily be found in the literature of the subject. The same may be said about the use of the term "vitality" by Professor Huxley and its relegation by him to the limbo of other defunct "itys." This, which has never ceased to be a red flag in the face of bellicose clergymen, was entirely within his province, and was merely a fine example of the exactness of definition of modern scientific nominalism. This misconception of the scientific use of abstraction appears in almost all the current criti-

cisms of the utterances of scientific men from a religious standpoint. The fundamental difference between the scientific and religious conception of nature consists almost wholly in the manner of regarding abstract terms. Causes—efficient and final—mind, life, and the whole category of vast abstract entities, are to the religionist the most real of all existences; to the scientist they are merely generalized expressions, binding together a large class of phenomena.

The term science does not, like the name of a religious sect, denote the belief in a set dogmatic formula, nor the acceptance of a certain class of ideas. There is no orthodoxy nor heterodoxy in science. On the contrary, the term science connotes the knowledge of the occurrence of certain phenomena in a certain definite order; and the term scientist denotes one who is versed in these facts, and who, from his knowledge of the past, is capable of making more or less probable guesses (hypotheses) as to the occurrence of these phenomena in the future, or in unexplored portions of the past. The attribution of more than this to the term science is not warranted. To say that true science teaches one thing and false science another is wrong. Science teaches nothing; it is itself knowledge rendered more exact. Vagueness of language and a looseness in the use of words lie at the root of many a difficulty. When we think of the numerous disputes that grow out of the misuse of words even on simple topics, and the difficulty there is in confining one's self to their pure signification, we can not wonder at this. It is a common defect in early education that pupils are not taught to attach sensible experiences to the words they repeat. Words are used with but an indefinite apprehension of the objects they are symbols of, and indistinct conception of the thought of others engenders indistinct thought in ourselves. It by no means suffices to establish the etymological meaning of words, for they are not, for the most part, scientifically constructed terms with precise significations, but are the result of the constant adaptation of old words to new uses, and are consequently often much distorted from their original meaning. Plato affords us an excellent model of the way to get at the meaning of terms. Take any of the Socratic dialogues and notice the trenchant manner in which the husks are severed from the true meaning of the words, and we see just what we must do with scientific terms if we would preserve their clearness. Should the logical teaching of our schools and colleges enforce this dialectical method as applied to scientific abstractions, we should see fewer attacks upon scientific men by those who utterly misapprehend their position.

It must be ever borne in mind that the scientist, as a scientist, has nothing to do with the metaphysical or theological implications of the words he uses. He employs them, as we have endeavored to point out, simply and purely to designate the occurrence of phenomena in a certain order which, could we sufficiently magnify our powers of observation, would be presented to our sensation in unequivocal terms.

When the scientist transcends these limits, and then only, he is going beyond the bounds of science. The temptation to stroll about, regardless of limits, is often great, and the scientist, like most of his kindred, frequently indulges in these aberrations. When thus found, he is entitled to no consideration on account of any sovereignty he may claim to exercise in his usual habitat, and, if overthrown, may be drawn and quartered at the will of his victorious enemy without a remonstrance being uttered by his fellow scientists. He thus occupies a dual position: in one the knowledge he possesses gives to his assertions a certain authority and to his hypotheses a certain probability of which they are devoid in the other. The discussion and consideration of religious questions by scientific men is a common illustration of this; but the attempt to throw the weight of scientific authority on to one side or the other of any question regarding supra-sensible objects should be steadily frowned down. The acceptance of a thorough nominalism in science and as thorough a realism in religion is by no means incompatible. Faraday is reported to have replied, to an inquiry as to how he, with his well-known scientific rigor of thought, could hold certain religious opinions, that he did not subject those opinions to scientific tests, as he well knew they could not survive them. Nevertheless, he held them as firmly as though convinced of their scientific soundness. The knowledge of the disintegration of the body after death may coexist with a strong religious faith in its resurrection. A large proportion of scientific men hold religious beliefs for which they have, and care for, no scientific justification. The logical soundness of such a position we will not here discuss. All that we care to do now is to assert most strongly that in science abstractions have no "real" existence, and that, when the scientist says that the explanation of certain powers of animal life by the term "vitality" is no explanation, or that consciousness is dependent upon organization, or uses any of the thousand and one kindred abstractions in a scientific sense, it is sheer meddling to interfere. Were the duty of keeping metaphysics at home inculcated with half the ardor that is used in urging science not to stray, we should hear much less of the conflict between religion and science. As it is, the modern Quixotes see in every scientific definition an imaginary giant, which it is their duty and privilege to destroy. Would they observe a little more closely, they would discover the harmless mechanism of the structure, and would reserve their energies for attacks upon more vulnerable enemies.

THE AGE OF ICE.*

By H. B. NORTON.

ANCIENT moraines, striations denoting the action of vanished glaciers, the lost rocks, clay-beds evidently of glacial origin—all these are evidences testifying that at some period not very remote, as we count geological periods, the whole northern hemisphere down to the southern limit of 40° was submerged and covered with vast glaciers and ice-floes. There is not a living scientist of any eminence who questions the truth of this assertion.

When we come to study the cause of these phenomena, we find many perplexing and contradictory theories in the field. A favorite one is that of vertical elevation. But it seems impossible to admit that the circle inclosed within the parallel of 40°—some 7,000 miles in diameter—could have been elevated to such a height as to produce this remarkable result. This would be a supposition hard to reconcile with the present proportion of land and water on the surface of the globe and with the phenomena of terrestrial contraction and gravitation. Moreover, it seems evident that an extensive submergence was one of the features of the glacial age. The frozen archipelago called Greenland is a fair picture of what northern America and Europe must have been at that time; and, of course, this precludes the idea of elevation.

If it were not true that submergence and a great lowering of temperature occurred simultaneously, we might imagine that a sort of undulation in the earth's crust, alternately raising and lowering each portion of it, could have caused this result. However, there is no evidence that such an undulatory motion has ever occurred, and we can not conceive of any force likely to produce it.

For the past fifty years, the relation of the inclination of the earth's axis to the plane of the ecliptic and its varying angle with the line of the apsides, has been the subject of careful study, from the impression that herein was a key to the mystery. Astronomical and geological works abound with hints and suggestions of this sort, but I have never yet seen any satisfactory analysis of the question. St. Pierre, Adhemar, and others have presented theories which seem strangely illogical in many of their conclusions. I have been striving to analyze the question, and will present a few of my conclusions.

The orbit of the earth is an ellipse, of which the sun occupies one of the foci. The major axis, or line of the apsides, is the longest diameter of the ellipse, passing through its two foci and through the points of perihelion and aphelion. This line is not fixed with respect

* Abstract of a lecture delivered before the Kansas Academy of Science.

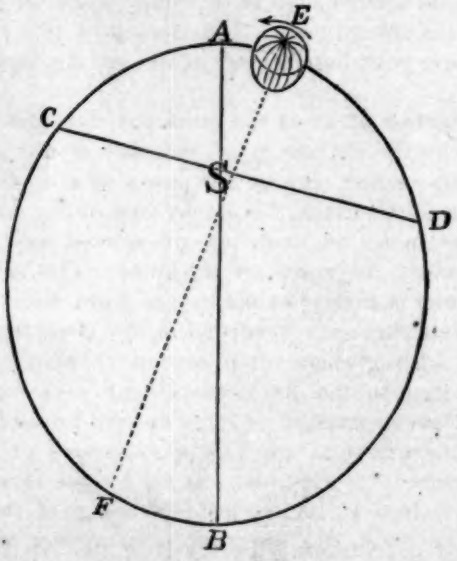
to the other bodies in space. Owing to the attractive force of the other planets, it is slowly revolving in the same direction that the earth moves in its orbit. The rate of revolution of this line of the apsides or major axis is a little over 11·6″ a year.

We ordinarily speak of the earth's axis as being always parallel to itself. It is, in fact, however, subject to a very slow gyratory motion, caused by the attraction of the sun upon the *meniscus*, or ring of matter bulging at the equator, which motion is retrograde, or in an opposite direction to the revolution of the earth. This retrograde motion causes the phenomenon known as the precession of the equinoxes. Its rate is about 50·3″ a year.

It will thus appear that a vast period of time will elapse before the earth's axis will occupy the same position with respect to the line of the apsides that it occupies to-day. This period is sometimes called the Great Year. Its length may be ascertained by reducing three hundred and sixty degrees to seconds, and dividing this quotient by the annual amount of the two motions described above :

$$1{,}296{,}000'' \div (50{\cdot}3'' + 11{\cdot}6'') = \frac{1296000''}{61{\cdot}9''} = 20{,}937.$$

The Great Year is thus seen to be about 21,000 years in length.



A, Perihelion; *B*, Aphelion; *E*, Winter Solstice; *F*, Summer Solstice; *D*, Autumnal Equinox; *C*, Vernal Equinox.

I have here drawn a diagram illustrating the present position of the earth's orbit with respect to the line of the apsides, purposely exaggerating the eccentricity of the ellipse in order to better present it to the eye of the observer. In the diagram, A B is the line of the

apsides; C and D are, respectively, the vernal and autumnal equinoxes; E F is the section of a plane passing through the poles of the earth at right angles with the plane of its orbit. It is evident that this plane will coincide with the line of the apsides once every 10,500 years; E is the winter solstice; F the summer solstice; C is the vernal equinox. While the earth is passing through B to D the north pole is inclined *toward* the sun. This period is the summer of the northern hemisphere.

D is the autumnal equinox. While the earth is passing from D through A to C, the north pole is inclined *from* the sun. This period is the winter of the northern hemisphere. In the southern hemisphere these seasons are reversed.

By consulting the diagram it will appear that the arc C B D is greater than the arc D A C. Therefore, the summer of the northern hemisphere is now longer than its winter. On the contrary, the winter of the southern hemisphere is now longer than its summer. At present, this difference is about eight days. It has been greater, but is gradually diminishing.

The southern hemisphere has at present a winter of 187 days, and a summer of 179 days. We may justly infer that during this winter more snow and ice accumulated at the south pole than the heat of the shorter summer is able to melt. The amount of this increase is very slight in a single year, but it accumulates a large aggregate in the course of ages.

This accumulation of ice at the south pole is continually increased and thickened by the deposition of moisture from the atmosphere. Every wind from warmer regions that passes over it adds to its mass.

The "Antarctic Continent" is an ice-cap, nearly circular in form, and about 3,000 miles in diameter, unexplored and uninhabitable. We can not easily ascertain its thickness. The arctic ice-cap is much smaller, and is honeycombed by the Kuro Siwa, or Japan Current, and the Gulf Stream. Nevertheless, the Greenland Archipelago seems covered with glaciers often several thousand feet in depth. If we could assign to the Antarctic ice-cap a thickness of 15,000 feet, we should have a mass of ice large enough to displace the earth's center of gravity nearly a mile to the southward of its center. A gradual displacement of this sort, caused by the slow accumulation of ice, would produce an imperceptible drainage of the oceans from the north to the south, and the gradual emergence of northern and submergence of southern continents.

If we examine the globe, we seem to discover an actual result of this sort. The greatest mass of the ocean is gathered about the south pole. The northern hemisphere includes about five sixths of the land-surface of the globe.

Moreover, geologists affirm that this inequality is increasing; they assert that the northern continents are slowly rising, and that the isl-

ands of the south Pacific are sinking. It is more probable that the water is slowly draining away from the northern hemisphere and accumulating in the southern. If our hypothesis be true, this process will continue for some thousand of years to come; until, through the submergence of southern lands and the extension of the Antarctic ice-cap, the condition of the southern hemisphere will approximate to that of the northern continents during their glacial age. Indeed, if the present position of the earth's axis with respect to the line of the apsides were invariable, we might expect to see a final complete submergence and refrigeration of the southern hemisphere.

But this position is not invariable. As I remarked above, it is slowly changing, making a complete revolution in 21,000 years. Refer to the diagram, and you will see that when F coincides with B, the winter of the southern hemisphere is longest; when F coincides with C, winter and summer in each hemisphere are of equal length; when F coincides with A, the summer of the southern hemisphere is longer than its winter. The earth occupies successively all these situations during its great cycle of 21,000 years. Each hemisphere passes through alternate periods of a preponderance of summer or winter; each period being 10,500 years.

There is one more factor in this problem which must be considered, and that is the periodical variation in the ellipticity of the earth's orbit. Sometimes the line of the apsides is longer than at other times. This variation occupies regular but vast periods of time. It is evident that when the variation is greatest, the accumulation of ice at the winter pole must be most rapid.

The 10,500 years during which the pole is refrigerated and deluged, may be called its great winter; the other half of the cycle, its great summer.

Unless astronomical calculations fail, the last great summer of the northern hemisphere commenced some 6,500 years ago. When it began, northern America, Europe, and Asia were frozen and deluged. The Arctic Ocean extended to a line south of the present bed of the Great Lakes. The Alps and the Alta were also southern boundaries of this ocean. Europe was the home of a swarthy, dwarfish race, who hunted the aurochs and great hairy mastodon at the foot of the glaciers that then half overflowed the continent.

But the intenser suns of many ages have done their work. The glaciers have melted, dwindled, retreated to the high Alpine valleys, and to the high northern latitudes. The swarthy troglodytes and lake-dwellers have followed them. Under the name of Esquimaux, Lapps, and Finns, a feeble remnant of these preadamite people still lingers within the Arctic Circle; but their doom as a living race seems near and sure. The Aryans have come marching across the Eastern steppes, for the building of society, civilization, human history.

In the outset of this argument, I assumed an Arctic ice-cap 15,000

feet in thickness, and a displacement of the earth's center of gravity one mile toward the north at the height of the glacial age. In fact, it is not necessary to assume any such amount of displacement. If the earth's center of gravity coincided with its center, so as to equalize the amount of water in the northern and southern hemispheres, Itasca Lake would not be more than 600 feet above sea-level. Now push the center of gravity 2,000 feet toward the north, and the Arctic Ocean would be so much deeper over the pole, and the water would be about 1,000 feet deeper at the latitude of 45°. To accomplish this result, we must calculate that the space within the Arctic Circle was covered by an ice-cap averaging perhaps 8,000 feet in thickness—an entirely supposable case. Such an amount of displacement would flood all the low lands of North America down to the line of 40°, and fully satisfy all the conditions of the problem.

It thus seems probable that there have been many glacial periods in each hemisphere, and that the ocean, like a mighty pendulum, vibrates from pole to pole through vast but regular periods. It is not necessary to suppose a cataclysm at the end of each period, as some of the earlier writers did; but rather, an insensible drainage of waters, which so gradually submerges the lands and pushes the human race before it, as hardly to be perceptible in the course of generations; ever uncovering new continents, and opening up fresh fields and pastures new to human industry, when the old are exhausted.

The southern hemisphere is now undergoing the slow refrigeration of its long winter. This began about 6,500 years ago; it will end about the year 4,870. It has passed its middle, but not its culmination, even as the greatest average cold of our ordinary winter is nearer the vernal equinox than the winter solstice. It is probable that, 2,000 years from now, the southern continents will be still more deeply deluged; the Antarctic ice-cap will have extended several hundred miles to the northward, and the glaciers which have already appeared among the Andes will have covered the plateaus of Patagonia and Chili. Nevertheless, we need not expect that mankind will then witness the utmost possible degree of refrigeration, because the ellipticity of the earth's orbit is now less than it has been at certain periods in the past, and will be again in the remote future.

I feel that, in this discourse, I have ventured upon doubtful and perilous ground. Nevertheless, however illogical and imperfect my conclusions may have been, I feel certain that herein is the key to the mystery. I leave the question, trusting that abler minds may be directed to its consideration and solution.

SKETCH OF PROFESSOR FRANKLAND.

AMONG the eminent men of England whose names are closely associated with the contemporary progress of chemical science that of Dr. Frankland has a distinguished place. Having a genius for the theoretical and speculative side of his favorite subject, together with a thorough and comprehensive discipline in experimental operations, he has devoted himself with equal zeal and success to pure chemistry, to its physical relations, and to its large applications to public and sanitary questions which depend for their elucidation upon chemical knowledge. Eminent also as a teacher and an organizer of research, and occupying many positions of responsibility, he has exerted a powerful influence in drawing students to this branch of study, and in awakening their enthusiasm in its pursuit.

EDWARD FRANKLAND, D. C. L., Ph. D., F. R. S., President of the Institute of Chemistry of Great Britain and Ireland and Professor of Chemistry in the Royal School of Mines, London, was born at Churchtown, near Lancaster, February 18, 1825. He was educated at the Lancaster Grammar School, and studied chemistry at the Museum of Practical Geology in London, under Lyon Playfair; and he was also a student at the Universities of Marburg and Giessen, where he worked in the laboratories of Bunsen and Liebig. At Marburg in 1849 he received the degree of Ph. D. when he presented a dissertation upon his discovery of a method for isolating the radical of alcohol and ether. In 1851 he was appointed Professor of Chemistry in Owens College, Manchester, and he also became Professor in St. Bartholomew's Hospital, London, in 1857. In 1863 he was appointed Professor of Chemistry at the Royal Institution of Great Britain, and in 1865 he succeeded Dr. Hofmann at the Royal College of Chemistry (School of Mines), then in Oxford Street, but since removed to South Kensington. He was elected Fellow of the Royal Society in 1853, and in 1870 he received the honorary degree of D. C. L. of Oxford.

In 1868 Dr. Frankland was appointed, in conjunction with Sir W. Denison, K. C. B., and J. Chalmers Norton, Esq., one of her Majesty's commissioners for inquiring into the pollution of rivers. The results of these inquiries were embodied in six reports presented to Parliament, five of them dealing with the pollution of rivers by the drainage of towns and manufactures, and the sixth with the domestic water-supply of Great Britain.

In 1871 he was elected President of the Chemical Society, and he became the first President of the Institute of Chemistry in 1877. All the chemical articles in the Arts and Sciences division of the English Cyclopædia were written by Dr. Frankland, or under his immediate supervision. The "Philosophical Transactions" for 1852 contain a long

memoir by him, entitled "On a New Series of Organic Bodies containing Metals." This important communication concludes with some theoretical considerations in which the analogy of the organo-metallic bodies with cacodyl is pointed out, and in which that character of elements which has since been termed "atomicity" was first described. In 1857 a royal medal was awarded him by the Royal Society for his "Researches on Organic Radicals and Organo-Metallic Bodies."

In the "Journal of the Chemical Society" (1866) Dr. Frankland published his "System of Notation" by which the formulæ of bodies are made to represent the mode in which the atoms composing them are arranged in accordance with their atomicity. This system has proved of great service in elucidating the causes of isomerism in organic compounds. His "Lecture Notes for Chemical Students" was published in 1866—third edition, two volumes, in 1876. His celebrated memoir, "On the Source of Muscular Power," was printed in the "Philosophical Magazine" in 1866. He gave a course of six lectures before the Royal College of Chemistry, entitled "How to teach Chemistry," which was summarized for publication by George Chaloner. Dr. Frankland is the author of numerous papers published from time to time in scientific periodicals, among which may be mentioned, "Observations Economical and Sanitary on the Employment of Chemical Light for Artificial Illumination"; "Contributions to the Knowledge of the Manufacture of Gas"; "Researches on the Influence of Atmospheric Pressure on the Light of Gas, Candle, and other Flames"; on "Winter Sanitariums in the Alps and Elsewhere"; on the "Purification of Town Drainage and other Polluted Liquids"; and on "The Composition and Qualities of Water used for Drinking and other Purposes." He is also the author, conjointly with Mr. J. Norman Lockyer, of "Researches connected with the Atmosphere of the Sun."

In 1857 Professor Frankland published "Experimental Researches in Pure, Applied, and Physical Chemistry." It forms a volume of over a thousand pages, which was issued by John Van Voorst, of London, and embraces the main researches of his scientific career. It has a very full table of contents, an exhaustive index, and a large number of illustrations of apparatus used in research; graphic tables are also included, representing to the eye the results of extensive series of experimental investigations. The volume embraces the records of experimental work in pure, applied, and physical chemistry, extending over thirty years, and scattered through many English and foreign transactions and journals. They are grouped into subjects and arranged chronologically, with a new introduction to each chapter, showing its scope, the relations of the several papers to each other, and their bearing on subsequent inquiries. A uniform system of nomenclature and notation is adopted (except in the section on applied chemistry), the principles of which are explained in an opening memoir. The work is thus unified, and, being carefully edited and revised so as to

give it the highest accuracy at the present time, it forms altogether a kind of comprehensive report upon the present state of the science in many of its most interesting and important aspects.

It may be remarked that the chemical inquiries detailed in this work took at first an analytical direction, with the object of isolating and identifying the proximate constituents or radicals of which organic compounds are constructed. Then they became synthetical, and were directed to the artificial building up or evolution of organic compounds. Some of these were already known as products of animal and vegetable life; while others, of at least equal complexity, were new additions to the category of organic bodies. In both cases their synthetical construction brought to light trustworthy evidence of their molecular architecture.

Dr. Frankland's investigations in applied chemistry, and especially those upon the purification of the sewage of towns, and the treatment of foul liquids from manufactories, and which were undertaken at the instigation of the Government, are most valuable. The results of the investigations on gas and water will be of service to engineers, manufacturers, agriculturists, local boards of health, and others interested either in the supply of gas and water to towns, the removal and utilization of foul drainage, or the health of populous places; for, in pursuing his inquiries Dr. Frankland did not confine himself to indispensable experiments and observations merely, but endeavored to discover the general principles underlying the various processes.

Dr. Frankland has been awarded honors from a large number of scientific bodies in England and on the Continent. He is Corresponding Member of the French Academy of Sciences; Foreign Member of the Royal Academy of Sciences in Bavaria; and of the Academies of Sciences of Berlin, St. Petersburg, and Bohemia. He is also Honorary Member of the Societies of Natural Sciences of Switzerland and of Göttingen; of the Literary and Philosophical Society of Manchester; of the Chemical Societies of Germany, America, and Lehigh University, United States; of the Sanitarian Society of Dresden, and of the Pharmaceutical Society of Great Britain.

CORRESPONDENCE.

SERPENT-CHARM.

Messrs. Editors.

IT would seem that, in his paper on "Serpent-Charm" in the September number of the "Monthly," Dr. Oswald overlooks a factor which is of too great importance to be wholly disregarded. That this is the case may be shown by an incident coming under my own observation, and two or three references.

While passing through a poultry-yard in September, 1878, I noticed a turkey-hen with neck stretched to the utmost, eyes fixed, and wings slightly raised, gazing most intently at some object on the ground three or four feet from where it stood. Watching it for some moments, I found that the turkey moved slowly around the attracting object in a circle, without withdrawing its gaze for a moment. After it had made a full circle, I approached to learn the cause of its extraordinary behavior, and found that the attracting object was a small striped snake partially concealed by some low weeds; and not until I touched it did the turkey notice my presence, though ordinarily it would not permit me to approach within two or three yards. Even when driven away, the turkey persisted in returning to fix its eyes on the little snake anew, when it would immediately cease to regard me in the least; and only when driven to the opposite corner of the large yard did it seem to forget its attraction to the spot.

Several other fowls, including chickens, other turkey-hens, and an old turkey-cock, were then driven singly in the direction of the snake, and each was found to be more or less affected on catching a glimpse of it, though most of them were satisfied to retire after viewing it attentively from several points. Nearly all, however, walked slowly entirely around it, and all extended their heads toward it in the most ludicrous manner. Finally, a flock of geese was driven by. On seeing the reptile they tipped their heads to one side and watched it attentively while they turned aside to pass around it, and, after all had passed in safety, expressed their relief by loud outcries.

Satisfied that the condition of the fowls, on seeing the reptile, was a purely subjective one, I approached to kill it, when, to my astonishment, I found it already dead, its head being crushed out of all semblance to its original shape, and covered with dust. I subsequently learned that it had been killed by a member of the family. I have since had two or three opportunities to verify the fact that fowls may be thrown into a condition in which volition seems to be partially or completely paralyzed by the sight of a perfectly harmless snake, and it seems to be almost wholly immaterial whether the reptile is alive or dead, provided it retains its natural form and position.

Monkeys are similarly affected by the sight of a snake, though they are not so completely paralyzed as fowls often are. Brehm relates that his monkeys were filled with dread on seeing some serpents, yet they "could not desist from occasionally satiating their horror in a most human fashion by lifting the lid of the box in which the snakes were kept"; and Darwin observed the same thing in the monkeys in the London Zoölogical Gardens, among which he introduced a stuffed snake: "After a time all the monkeys collected round it in a large circle, and, staring intently, presented a most ludicrous appearance. They became extremely nervous, so that when a wooden ball, with which they were familiar as a plaything, was accidentally moved in the straw, under which it was partly hidden, they all instantly started away. . . . I then placed a live snake in a paper bag, with the mouth loosely closed, in one of the larger compartments. One of the monkeys immediately approached, cautiously opened the bag a little, peeped in, and instantly dashed away. Then I witnessed what Brehm has described, for monkey after monkey, with head raised high and turned on one side, could not resist taking a momentary peep into the upright bag, at the dreadful object lying quietly at the bottom." ("Descent of Man," Appletons, 1877, pp. 71, 72.) Similar excitement was exhibited by the monkeys in the Philadelphia Zoölogical Gardens, when a dead snake was placed in their cage, as recorded by Mr. A. E. Brown in "The American Naturalist," and quoted in "The Popular Science Monthly" for July, 1878 (Vol. XIII., p. 379).

The condition into which these monkeys —and more particularly the fowls mentioned above—are thrown on seeing the frightful object is so nearly identical in its causes and its manifestations to hypnotism or kataplexy as to indicate a very intimate relationship therewith; and to this condition many birds and small animals are extremely subject. "Preyer has succeeded in rendering kataplectic various species of toads, newts, frogs, ducks, poultry, peafowl, par-

tridges, sparrows, mice, Guinea-pigs, rabbits, etc." ("Popular Science Monthly Supplement," xviii., p. 574); and he considers that fear is the chief cause of the inhibition of spontaneity. In view of these premises it seems not improbable that the same species might pass into a similar subjective condition on being suddenly brought in view of serpents, of which all of these animals stand in great dread. Indeed, this is in substance the explanation of serpent-charm given by Dr. Preyer himself. Granting this, it is easy to see that the ophidians, whose intelligence is, according to Darwin (ib., 352), "greater than might have been anticipated," would be likely to learn to take advantage of it. As soon as this took place, serpent-charm would be practically established as a factor in the animal economy, though perhaps a very unimportant one; and in corroboration we have the evidence of Preyer and several other naturalists, who accept the "fascination of birds by snakes" as a scientific fact; while, as Dr. Oswald admits, we have the testimony of eminent ophiologists that snakes are unable to capture birds unless aided in some manner. Of course it is not yet established by competent observers that small birds and animals do actually pass into a subjective condition on seeing a snake (and the evidence adduced by Dr. Oswald is of a negative character), but it seems more probable that this is so than that the few skilled and the many unskilled observers should have erred so egregiously; and it is certainly much more probable than that the popular notions regarding serpent-charm should have originated in the aimless struggles of birds or small animals wounded to the death by the fangs of a venomous serpent.

Very truly yours,

W. J. McGee.

Farley, Iowa, *September* 1, 1879.

EDITOR'S TABLE.

THE SCIENTIFIC ASSOCIATIONS.

THE scientists had a profitable and pleasant time at Saratoga. The twenty-eighth annual meeting of the American Association for the Advancement of Science, which met there this year, was well attended and successful in every respect. A larger number than usual of the old and eminent members of the body were present, and that the gathering represented a goodly proportion of the scientific working power of the country is shown by the fact that about one hundred and fifty papers were contributed, in different fields of inquiry, many of which were of marked merit. There are two or three respects in which the proceedings were noteworthy, and to which we desire to call attention.

The American Association was formed upon the model of the British Association, which had been in operation for some years, and incorporated its main features. They embrace common objects, and have both undergone a development that has accompanied the progress and widening of scientific thought. Their annual sessions occur so nearly together that the contributions from both sources come upon us at the same time; and, regarding them as substantially one organization, we select their papers for printing by the rule of convenience. The able inaugural address of President Allman at the Sheffield meeting appears in our present number, and we shall publish a revised edition, with notes, of the equally able address of Professor Marsh at Saratoga in our next issue. In his address before the Physiological Section of the British Association, over which he presided, Dr. P. H. Pye-Smith stated the leading objects of the organization, as follows:

"The Association to which we belong seeks to advance natural science, that is, accurate knowledge of the material world, by the following means:

"1. By bringing together men who are engaged in the various fields of science indicated by our several sections, by promoting friendship between them, by giving opportunity for discussion on points of difference, by encouraging obscure but genuine laborers with the applause of the leaders whom they

have learned to venerate, and by fostering that feeling of respect for other branches of science, that knowledge of and interest in their progress, which chiefly mark the liberality of scientific study.

"2. The Association provides funds which, though small in amount, are great in worth, from the mode of their distribution; and serve in a limited degree as an encouragement, though not an endowment, of research.

"The third most important aim of our Association is, 'to obtain a more general attention to the objects and methods of science, and the removal of any disadvantages of a public kind which impede its progress.' It is for this reason that the Association travels from one to another of the great centers of population and intellectual activity of the kingdom, local scientific societies and local museums are generated and regenerated in its path, local industries are for a time raised to a higher level than that of money-getting, and every artisan may learn how his own craft depends upon knowledge of the facts of nature, and how he forms part of the great system of applied science which is subduing the earth and all its powers to the use of man. We wish to make science popular, not by deceiving idlers into the belief that any thorough knowledge can be easy, but by exciting interest in its objects, and appreciation of its methods. In the popular evening lectures you will hear those who are best qualified to speak upon their several subjects, not preaching with the dry austerity of a pedant, but bringing their own enthusiasm to kindle a contagious fire in those who hear them."

Of course the prime object of these bodies is the promotion of science by means of original investigation and the development of new views; but it is not for a moment to be overlooked that these objects can only be efficiently secured by appropriate means. Experimental investigations and systematic observations on the varied phenomena that solicit inquiry are only to be made by outlays of time, labor, and money. The scattered students of original science work generally alone, and with such facilities as they may be able to command; but it is one legitimate object of combination to enlarge the opportunities of research, and give help and encouragement to isolated inquirers. Occasions, moreover, are constantly arising in which investigations become so comprehensive and methodical that they can not be carried on by individual resources, and outside aid is indispensable. It has been an important part of the policy of the British Association to furnish means for carrying on various investigations of this kind, the results of which are reported at its annual sessions; and, from the outset, one of its objects has been to raise money for such purposes. Funds thus appropriated, as Dr. Pye-Smith remarked, serve as an encouragement to research without becoming a formal endowment. The Association marks out or approves a course of inquiry, and then gives substantial assistance in carrying it on to parties especially qualified for the work; and thus the utmost equivalent for the money expended is certain to be secured. This admirable feature of the British Association ought to be initiated and developed by our own society, and to this end we venture to think there should be more systematic effort to secure voluntary contributions. The American Association has not abounded in worldly wisdom to anything like the degree that its nationality would justify. Absorption in pure scientific work seems to have been unfavorable to the practical business element. This has limited the usefulness and efficiency of the organization, for money is as much the sinew of science as of war. It is to be hoped that in future increasing attention will be given to this sub-

ject; and that a special department of the society will be constituted a committee of ways and means to raise contributions and devise expedients for enlarging its usefulness.

But, though the American Association has not hitherto developed much financial skill, it is gratifying to note that it is making increasing efforts to excite public interest in its objects. Undoubtedly, the great impediment to scientific progress is popular ignorance, indifference, and lack of sympathy with the aims to which men of science are devoted. The energy, the culture, and the influence of the active classes of society are not sufficiently enlisted in behalf of this work. It is in the line of its legitimate duty for the Association to take advantage of its opportunities, as it yearly passes from city to city, to present the claims of science to the public in such a manner as to arouse enthusiasm in their behalf. Lectures to the people by able men on a variety of subjects might be easily provided for at the annual sessions, without any impairment of the legitimate work of the sections. The Saratoga meeting, we are glad to note, manifested a decided tendency to fall in with this policy. Besides the popular character of the addresses of the President and of the Vice-Presidents, advantage was taken of the opportunities afforded by the locality to give a public entertainment, both thoroughly scientific and of interest to all classes. An evening was given to the mineral waters, and three of the ablest scientific men present made addresses of great interest on the different aspects of the subject. Professor Chandler, who has analyzed most of the waters, spoke of their composition, properties, and the characters of the different springs, illustrating his remarks by appropriate experiments, and extensive tabular statements. Professor Hall, the distinguished New York geologist, took up the relation of the rock formations to these fountains, and dwelt upon the history of those disturbances in the strata which have given rise to this extensive group of mineral springs throughout a valley which yields a new water at every boring. Dr. Sterry Hunt followed, with a most interesting and impressive address on those ancient conditions and transformations of the earth's crust which explain the genesis of this class of waters. By his profound studies of geological chemistry he was enabled to throw much light on the nature and origin of mineral springs; and, like the speakers who preceded him, he deeply interested the large audience who listened to his admirable exposition. It was altogether a happy illustration of what it is possible for the Association to accomplish in the way of first-class popular work.

Another consideration is pertinent here from this general point of view. The predominant movement of scientific thought is toward subjects which take a powerful hold of the popular imagination. Biology is the great science of the latter half of the nineteenth century. The mathematics, physics, and chemistry—the exploration of inorganic nature of the past three hundred years—are but the preparation for entering upon the exhaustive original study of the science of life. There was long a belief in its impossibility, and something like a dread of engaging with it; but that period is now past, and the advanced scientific mind of the world has entered in earnest upon the multitudinous problems offered by living beings, from invisible creatures, revealed by the microscope, up to man and his complex social relations. Science has slowly but steadily approached those elevated vital questions in which all intelligent persons have an acknowledged concern, and how completely these questions are now in the ascendant is shown by the leading discussions in both the American and the British Associations for the Advancement of Science. President Marsh considered the history of

the investigations into the earth's extinct life, and pointed out that the high ground of evolution has been gained, and that it is no longer an open question, but must be accepted for the guidance of future research; while all the tendencies of thought converge toward the conclusion which the future will realize, that inorganic and organic nature will yet become one. Dr. Ullman, also assuming the truth of evolution, enriches our biological literature with an elaborate essay on that remarkable substance, only made known in quite recent times, which turns out to be the common medium and substratum of all vital manifestations—the liquid protoplasm. Professor Mivart and Dr. Pye-Smith, in their inaugural addresses as Vice-Presidents, still further devote themselves to biology and natural history, while Powell and Tylor open the extensive subject of anthropology. Biological studies, of course, issue in the science of man, involving a broad series of questions, organic, psychological, developmental, racial, and social, and these questions now occupy the central arena of interest and debate. Anthropology has long been a prominent subject in the British Association, although for many years it had to battle for formal recognition and the important position that is now accorded to it. It has now come forward in the American Association, and the status conceded to it is sufficiently shown by the fact that the President-elect, who will preside at the Boston meeting next year, Mr. Lewis H. Morgan, is the first special representative of anthropology who has attained this honor.

These circumstances illustrate the powerful drift of contemporary science in the direction of those higher human questions which have claims upon intelligent people of all classes. So long as science was supposed to busy itself solely with distant, curious, and useless things, it was very naturally an object of thoughtless derision to minds occupied with pressing interests and claiming to be "practical." But these superficial sarcasms have lost their point in these latter days, when science is everywhere giving law to the practical, and is now addressing itself systematically to the most directly important of all subjects—the laws of life, and the nature of man and his institutions. This is the field that now most needs cultivation, and the Associations which are devoted to improvement and diffusion of accurate and trustworthy knowledge upon these subjects are entitled to the liberal patronage of the public.

LITERARY NOTICES.

A Sketch of Dickinson College, Pennsylvania: Including the List of Trustees and Faculty from the Foundation, and a more Particular Account of the Scientific Department. By Charles F. Himes, Ph. D., Professor of Natural Science. Illustrated by Engravings and by Photographs executed in the Laboratory. Harrisburg: Lane S. Hart. Pp. 155. Price, $2.

This neat little history of Dickinson College, with its portraits of the founder and of its leading presidents, its admirable photographs of the college buildings, and its illustrations of historic relics in its laboratory, will be much prized by all who are interested in the institution, and is by no means without instructiveness to general readers who care about the progress of education. Dickinson College, located at Carlisle, Pennsylvania, in the beautiful Cumberland Valley, was founded in 1783, and named after John Dickinson, Governor of the State, who was active in its establishment, and made liberal donations to it. Dr. Benjamin Rush was also deeply interested in the institution from the beginning, and labored zealously for twenty-five years in various ways to promote its success. The college has had a successful career and a creditable history, and includes among its alumni a President of the United States, a Chief Justice, with many judges, senators, Cabinet officers, Congressmen, and professional men of high rank. Among the distinguished men who

have occupied chairs in its Faculty may be mentioned Professor Henry D. Rogers; Professor Spencer F. Baird, now at the head of the Smithsonian Institution; and the celebrated Dr. Thomas Cooper, who subsequently became a judge and President of South Carolina College. Judge Cooper, as Professor Himes aptly remarks, was "one of the most remarkable products of the complexity of moral and intellectual forces of the closing quarter of the last century." He was a man of great erudition and independence, and a forcible writer. "A native of England, educated at Oxford, on terms of intimacy with Pitt, Burke, and other leading English statesmen, a resident of Paris during the four months of the Reign of Terror, and enjoying its excitement to the full, he was a radical in politics and a materialist in creed. A friend of Priestley, he shared with the latter his exile from his country, and enjoyed the use of his library and laboratory in Northumberland." Dr. Cooper was elected to the chair of Chemistry and Mineralogy in Dickinson College in 1811, and occupied it for four years. His introductory lecture on chemistry was remarkable for being one of the first scientific lectures published in the country. It was exhaustive, and displayed a wonderful range of information. The lecture itself filled one hundred pages, octavo, and its accompanying notes one hundred and thirty-five pages more. He purchased the telescope, air-gun, and burning-lens used by Dr. Priestley, which are carefully preserved in the college collection.

Professor Himes's account of the growth of the scientific department of the college is interesting as a chapter in the history of education. A revolution is there sketched which it is proposed to consummate in a century of collegiate experience. Although science was becoming active when the college was founded, yet scientific study as a part of education was in its infancy, while theology and cognate subjects were all-prevailing. The first question in regard to science, therefore, was, how it would affect religion. The first President was Dr. Nesbit, an able Scotch divine; and we are told that, on a visit to Governor Dickinson, an evening was spent in the discussion of the theological relations of science, in which Nesbit maintained that, "unless the grace of God produced a different effect, the more intimately men became acquainted with the works of nature, the less mindful were they of their great Author." Theology, therefore, led one way and science another; and yet, under the act of incorporation, of the forty members comprising the Board of Trustees more than one third were required to be clergymen; while every one of the fourteen presidents which the college has had has been a doctor of divinity. It is therefore to be expected that the college would favor the kind of learning that has proved of utility in the avocation of preaching. Important concessions have, however, been made in the direction of liberal studies. There is the ordinary four years' college course with its load of two dead languages, and which is probably much the same as it was a hundred years ago. But there is also a Latin-scientific course from which half the dead weight has been unloaded, and so it is brought into three years. But the scientific spirit has made great progress, as is shown by the fact that the centennial of the institution in 1883 is to be crowned by the dedication of a new and elegant building devoted entirely to scientific purposes.

DIE ENTWICKLUNG DES MENSCHENGESCHLECHTES. VON DR. ADELRICH STEINACH. New York: The Author, 122 Allen Street. 1878. Pp. 681. Price, $2.50.

THIS treatise forms the second volume of a "System of Organic Evolution," but the first volume, "The Evolution of the Plant and Animal World," is not yet published. The author adopts the Darwinian (or evolutionist) point of view throughout, but, unlike most of the German followers of Mr. Darwin, he adheres to that school of philosophy which is opposed to materialism. The present installment of Dr. Steinach's work, "The Evolution of the Human Race," is marked by profound learning and no small degree of originality. We have not space to review it at length, and must content ourselves with briefly indicating its contents. It is divided into three parts, entitled—"I. Man in Space"; "II. Man in Time"; and "III. The Evolution of Mind." In Part I. the author considers man in his relations to his environment, and strives to show how his mental and physical develop-

ment is conditioned by the forces acting upon him from without. In Part II. we have chapters on the "Origin of the Human Race"; "Prehistoric Relics"; "Centers of Creation"; and "Dispersion of the Human Race." Finally, in Part III., the author treats of "The Development of the Psychic Faculties"; "The Development of Language"; and "The Development of Civilization." Under the last-named head are chapters on the development of religious and moral ideas, of social relations, and of scientific and industrial activities.

THE PHILOSOPHY OF MUSIC. Being the Substance of a Course of Lectures delivered at the Royal Institution of Great Britain in February and March, 1877. By WILLIAM POLE, F. R. S., etc. Boston: Houghton, Osgood & Co. 1879.

IT is doubtful whether the musical public is in any degree aware of the revolutionizing contribution which contemporary scientific investigation is making to the theory of music, building a solid structure where before lay an interminable swamp of bad logic, fanciful speculation, and impossible metaphysics. Yet it was as long ago as 1863 that Helmholtz published his large epoch-making work ("The Sensations of Tone as a Physiological Basis for the Theory of Music"). Mr. Ellis in 1875 furnished an excellent English translation, adding several learned appendices of his own; and James Sully, Grant Allen, and others have written brief expository chapters and essays on Helmholtz's theory. A few years ago a society was organized in London for the study and propagation of the new order that had come into the complexities of musical theory. Mr. William Spottiswoode was president. It was at the invitation of Mr. Spottiswoode, as secretary of the Royal Society, that Mr. William Pole delivered at the Royal Institution of Great Britain the lectures on "The Philosophy of Music," which now appear in the book of that title.

This work for the first time places before the non-scientific reader a full, well-proportioned, and easily followed exposition of the new illumination which has fallen upon speculative music. This is a most important task, and to have performed it so well as Mr. Pole has done is a merit almost equal to that of original investigation. For the subject is burdened with a mass of historical and technical minutiæ that required the most careful sifting out of the non-essential; then came the task of leading the uninitiated reader to entirely new conceptions, and of eradicating or directly inverting many old and long-established ones. Altogether a more trying subject for the expository art could not have been found, and it is not too much to say that the musical reader may find in these twenty-one orderly chapters something beyond their subject-matter, viz., an excellent illustration of the systematizing and clarifying influence that scientific methods may have upon mental activity.

The author, preparing the way with a chapter on elementary acoustics, states the phenomena of overtones, and then shows their action in determining the tone-character or timbre of the various musical instruments. These overtones also constitute the natural basis for the scales, for melody, tonality, and harmony—in so far as these have a natural basis. For æsthetical influences, local, individual, and transitory, have played the largest part in giving to music its present form. The problem is to determine the parts played, on the one hand, by physical or physiological principles, on the other by æsthetical requirements, in that artistic growth which has from the simple Greek tetrachord developed modern music in all its complexity.

As to the origin of the diatonic scale, following Helmholtz always, the author believes the octave and its primary division into fifth and fourth to have arisen from the natural structure of a musical sound, which by its overtones embraces these three intervals. The octave, with its fifth and fourth, admitted of seven different divisions, the seven Greek modes. From these the requirements of early ecclesiastical music eliminated two modes, leaving five. The coming of harmony, under Palestrina, removed three more modes, unsuitable because of their paucity in concords; and the remaining two survive as our modern major and minor.* This gradual change, a genuine

* In showing this eliminative process an unfortunate mistake is made on page 134, the repetition of which on the following page seems to give it some weight. D forms with G not a perfect *fifth*, but a perfect *fourth*.

survival of the fittest, is made admirably clear by the graphical method of plotting the scale on paper; using the logarithms of the intervals for magnitudes. By the same method the complexities of the chromatic scale and of equal temperament are made easily comprehensible to careful reading.

After briefly considering the questions of time and form (Chapter XIII.) the *structure of music* (Part III.) is taken up. What use is made of the scales whose origin is traced in Part II.? What is due to natural laws, what to æsthetical influences? The position taken with regard to melody does not seem as strong as it might be. "The earliest forms of music probably arose out of the natural inflections of the voice in speaking." This is Spencer's theory. It is not mentioned that Darwin combats this, placing the origin of melody in the love-songs of man's early ancestors, before speech began; or that Helmholtz attributes the expressiveness of melody to its motion, which translates into vocal ordinates, as it were, the varying intensities of the emotions. It is shown in the "American Naturalist" (April, 1879, "Animal Music," etc.) that if the overtone structure of sounds has impressed itself upon the internal ear, the most easy progression of a melody will be along the intervals existing between overtones, viz., octaves, fifths, fourths, etc. This offers a much more natural basis for melody and scale origin than the theory of Helmholtz, repeated by Mr. Pole, according to which a certain connection is established between notes, an octave, a fifth, etc., apart by the *mind's recognition* of their possessing common overtones. This is a psychological, not a physiological basis.

In treating harmony, the natural element, viz., the rough beating of dissonant tones, is given due emphasis, and the dominance of æsthetical arbitrariness over this natural element fully shown. The fallacy of the *argumentum ad aurem*, so much used by theoretical musicians, is exposed. In the simplest elements of music the ear has no doubt been the guide, but the appeal to the ear is often carried too far. "We approve certain things not because there is any natural *propriety* in them, but because we have been accustomed to them, and have been taught to consider them right," and *vice versa* with our disapprovals. Chapter XVIII. greatly simplifies thorough bass by analyzing all the chords into their binary components, and investigating the harmonic character of these; not assuming in the usual way that every chord must have one root, but accepting Rameau's more rational view that there may be two. The last three chapters comprise harmonic progressions and counterpoint simply treated, and a good summary of the whole book.

The only improvements that could be wished are that the radical importance of the physical basis had been more firmly insisted upon, for, whatever may be the afterchanges, this basis permeates and controls everywhere; and that the æsthetic influence had not been made to seem so entirely an incalculable matter of chance. This influence has laws of its own, and has been quite successfully investigated by James Sully in the two chapters of his "Sensation and Intuition" entitled "The Aspects of Beauty in Musical Form," and "The Nature and Limits of Musical Expression." These chapters, written in a most quiet and unassuming way, are rich in penetrating analysis made in full sympathy with the artistic side of music, yet with all the exactness and fertility of the scientific method. A brief showing of their trend would have enriched Mr. Pole's work, and have made his treatment more complete.

LABORATORY TEACHING; OR, PROGRESSIVE EXERCISES IN PRACTICAL CHEMISTRY. By CHARLES LOUDON BLOXAM, Professor of Chemistry in King's College, London; in the Department of Artillery Studies, Woolwich; and in the Royal Military Academy, Woolwich. Fourth edition, with Eighty-nine Illustrations. Philadelphia: Lindsay & Blakiston. Pp. 261. Price, $1.75.

THE name of Professor Bloxam is the best assurance of the merit of this volume. The book does not presuppose any knowledge of chemistry on the part of the pupil, and does not enter into any theoretical speculations. It dispenses with the use of all costly apparatus and chemicals, and is divided into separate exercises or lessons with examples for practice to facilitate the instruction of large classes. The method of instruction followed has been adopted by

the author after twenty-three years' experience as a teacher in the laboratory, by which, as he says, he has been led to conclude that a knowledge of analytical chemistry, or the power of discovering the nature of unknown substances, is the first and often the only requirement of the great majority of learners, and that independently of the technical value of such knowledge, its acquisition forms a most valuable part of education by cultivating the powers of observation, and affording excellent examples of the application of logical reasoning in practical work.

ANALYSIS OF THE URINE, WITH SPECIAL REFERENCE TO THE DISEASES OF THE GENITO-URINARY ORGANS. By K. B. HOFMANN, Professor in the University of Gratz, and R. ULTZMANN, Docent in the University of Vienna. Translated by T. BARTON BRUNE, A. M., M. D., Resident Physician, Maryland University Hospital, and H. HOLBROOK CURTIS, Ph. B. With numerous Colored Plates. New York: D. Appleton & Co. 1879. Pp. 269. Price, $2.

IT is gratifying to note the various indications of progress in popular journalism. While, as all can see, it is steadily advancing toward such lofty literary ideals as are exemplified by the writings of Macaulay and Froude, there is also encouraging promise that it is aspiring to a more elevated standard of purity and ethical taste. Especially when we observe a newspaper struggling and tempted, yet scorning all sordid considerations in the inflexible determination to maintain an exalted moral tone, so as never to wound the delicate sensibilities of its most fastidious readers, we are led to entertain glowing anticipations of the future of the American press. Our present enthusiasm is kindled by the refusal of the "New York Herald" to insert in its columns an advertisement of the book which bears the above title. But we can admire where it is impossible to imitate.

The importance of this subject has always been acknowledged in the medical profession. Hippocrates (400 B. C.) directed attention to the character of the renal excretion, and its changes of color, clearness, and its sediments, in connection with diseased conditions of the body; and he even endeavored to demonstrate the influence of various foods and drinks upon its constitution. The Arabian Avicenna (A. D. 1000) called attention to the fact that different external circumstances, as fasting, wakefulness, over-exertion, and strong emotions have an influence upon the character of the urine. Actuarius, in the thirteenth century, advanced the knowledge of the subject so far that it became an object of satire with poets and painters. Bellini (1675) investigated the proportion of solid constituents to the contained water. Willis discovered sugar in the urine, and Brandt obtained phosphorus from it. Rouelle discovered urea (1773). In 1770 Cotugno found pus in it; and in 1798 Cruikshank declared the relation of this condition to dropsy. In 1827 Bright proved the connection between kidney-disease and albuminuria; and Rayers's researches (1841) laid the foundation of our present knowledge of kidney-diseases. Since that time many observers have turned their attention to the subject; while the great advances of chemical, microscopical, and physical science have told effectively upon this branch of investigation. The urine indicates, at least very nearly, by its qualitative and quantitative changes the variation in tissue life, and it thus affords invaluable tests of the presence of disease; while its analysis, so far as it interests the practicing physician, can be made with simple apparatus. This volume, concise in form, and full of practical hints and valuable suggestions regarding both analysis and diagnosis, supplies a need that has been long felt by American students and physicians; while its merit is well attested by the fact that it appeared in three languages during the year of its publication.

A DICTIONARY OF MUSIC AND MUSICIANS (A. D. 1450–1879). By Eminent Writers, English and Foreign. With Illustrations and Woodcuts. Edited by GEORGE GROVE, D. C. L. Part VII. London and New York: Macmillan & Co. Pp. 128. Price $1.25.

ANOTHER installment has come of this entertaining serial, filled with the art, science, history, biography, criticism, and miscellaneous erudition of music. The work is being faithfully executed, and keeps up its excellent character.

AN INTRODUCTION TO THE PRACTICE OF COMMERCIAL ORGANIC ANALYSIS: Being a Treatise on the Properties, Proximate Analytical Examination, and Modes of Assaying the Various Organic Chemicals and Preparations employed in the Arts, Manufactures, Medicine, etc. With Concise Methods for the Detection and Determination of their Impurities, Adulterations, and Products of Decomposition. By ALFRED H. ALLEN, F. C. S., Lecturer on Chemistry at the Sheffield School of Medicine, Fellow of the Institute of Chemistry of Great Britain and Ireland, Public Analyst for the West Riding of Yorkshire, the Northern Division of Derbyshire, and the Boroughs of Sheffield, Chesterfield, Barnsley, etc. Vol. I. Cyanogen Compounds, Alcohols and their Derivatives, Phenols, Acids, etc. Philadelphia: Lindsay & Blakiston. Pp. 360. Price, $3.50.

THIS useful volume is the first part of an ample treatise which will be carried out if the reception of the present portion justifies the compilation of the second volume. The author has been moved to its preparation by a conviction of the palpable deficiency in this branch of chemical literature. While manuals of inorganic analysis abound, books on organic analysis, the author avers, are chiefly conspicuous by their absence. He says: "It is a lamentable fact that while our young chemists are taught to execute ultimate organic analyses and to ring the changes on the everlasting chloro, bromo, and nitro derivatives of bodies of the aromatic series, the course of instruction in many of our leading laboratories does not include even qualitative tests for such every-day substances as alcohol, chloroform, glycerine, carbolic acid, and quinine. As a natural consequence of this neglect, the methods for the proximate analysis of organic mixtures and for the assay of commercial organic products are in a far more backward state than is justified by the great inherent difficulties of this branch of analysis.

"Having in my own practice as a consulting chemist repeatedly felt the need of a convenient hand-book containing all reliable information respecting the methods of assaying and analyzing organic substances in common use, I presume that others will have suffered similar experiences, and hence that a work on the subject will 'supply a want which has long been felt.'

"In the arrangement of the subject-matter I have ignored the more obscure relationships, and have preferred grouping the bodies treated of in a manner which it is hoped will be found convenient for practical reference, though such an arrangement has necessitated some inconsistencies."

THE RELATIONS OF MIND AND BRAIN. By HENRY CALDERWOOD, LL.D., Professor of Moral Philosophy in the University of Edinburgh. New York: Macmillan & Co. Pp. 455. Price, $4.

IN the progress of modern psychology the organic side, or corporeal conditions of mind, has been brought into constantly increasing prominence, until now it is no longer denied that cerebral physiology is, if not a foundation, at least an essential part of mental science. But the necessity of having to mix up cells, fibers, blood capillaries, and protoplasmic pulp with subtile and refined mental operations, has been looked upon with great repugnance by the old-school metaphysicians. It has virtually divided them into two parties, one of which raises the cry of "Materialism!" and will have nothing to do with the new heresies; while the other accepts the situation, and is only anxious that the new views are not pushed too far. Among these more rational devotees of mental philosophy is Professor Calderwood, who, approaching the subject from the metaphysical side, has entered into the general inquiry of the physiological relations of the human mind. He thus explains the purpose of his book: "The object of the present work is to ascertain what theory of mental life is warranted on strictly scientific evidence. The order followed is to consider—1. The latest results of anatomical and physiological research as to the structure and functions of the brain; 2. The facts in human life unaccounted for by anatomical and physiological science, and requiring to be assigned to a higher nature. On the side of mental philosophy it must be recognized that analysis of consciousness can not be regarded as affording a complete survey of the facts of personal life. On the other hand, it is clear that the known facts connected with cerebral action do not include familiar phases of mental activity. If we allow ourselves to be engrossed with physiological investigations as to brain, we restrict our attention to a single class of

facts, and become unable to take a view of human life as a totality. The whole range of evidence must be traversed if we are to secure an harmonious representation of the constitution of human nature." The book has not been produced in the pure spirit of science, but under a bias, and to sustain a foregone conclusion; yet the work is done with ability, and will be useful.

THE ROUND TRIP BY WAY OF PANAMA, THROUGH CALIFORNIA, OREGON, NEVADA, UTAH, IDAHO, AND COLORADO. By JOHN CODMAN. New York: Putnam's Sons. 1879. Pp. 331. Price, $1.50.

THIS is a truly valuable book of travel. The author is a keen observer of man and of nature; and, moreover, he is a skilled literary artist. He sees with his own eyes, and not through the eyes of a guide-book writer, and he carefully eschews the commonplace. He writes of the railroads, commerce, agriculture, mining, scenery, and populations of the great States and Territories visited on the "Round Trip."

LECTURES ON THE HISTORY OF ENGLAND. By M. J. GUEST. London: Macmillan. 1879. Pp. 598, with Maps. Price, $1.75.

THE author offers in his preface an apology for adding to the already over-large number of "Histories of England." Having to deliver lectures to men and women (working people, presumably) on English history, he found, on beginning to prepare his lessons, "no one book which was not either too learned, too copious, too trivial, or too condensed." Plainly, then, there was still room for one history more. Special indebtedness is acknowledged to Green's "History of the English People."

A COMPLETE SCIENTIFIC GRAMMAR OF THE ENGLISH LANGUAGE. By W. COLEGROVE. New York: The Authors' Publishing Co. 1879. Pp. 362.

IN the preface to this book it is said that "at present English grammar is in the same condition in which Copernicus found astronomy." The author appears to be pretty confident that his work has established the "reign of law" in this chaos, and that henceforth grammar is to rank as a "science" in the strictest sense of that term.

FREE RELIGIOUS ASSOCIATION. Proceedings at the Twelfth Annual Meeting of the Free Religious Association, held in Boston, May 29 and 30, 1879. Boston: Free Religious Association. Pp. 79. Price, 25 cts.

THE "Free Religious Association" is one of the extreme reactions against the restrictive spirit of ecclesiasticism which is still dominant in modern society. That spirit has unquestionably declined in power with the rise and advance of scientific thought. Protestantism was a revolt against the tyranny of the older religious organizations. The liberal Christianity of our own century was, again, a revolt against the spiritual repressions of Protestantism. And now "free religion" carries on the liberating work still further by rebelling against the restrictions of liberal Christian theology. Something is gained to freedom of religious thought at each step, and the advance movement is ever engaged upon a wholesome and necessary work. The "Free Religious Association" announces its objects to be, to promote the practical interests of pure religion, to increase fellowship in the spirit, and to encourage the scientific study of man's religious nature and history. It avows no creed, but leaves each individual member responsible for his own opinions alone, and declares that nothing in its constitution shall ever be construed as limiting membership by any test of speculative opinion or belief, or as interfering in any other way with that absolute freedom of thought and expression which is the natural right of every rational being.

It would seem to be impossible to go further in the declaration of religious freedom. Nothing remains to be gained on that score. Yet the Association does not at all admit that it is therefore out of business. It has important ethical objects to secure, and therefore plenty to do. In fact, free religion itself is held to be a means of attaining exalted moral ideals, and from this point of view it has before it endless occupation and a positive basis of union. Beliefs, views, doctrines now come in order, and there seems to be the necessity of something resembling a creed or declaration of convictions. The need of some groundwork, or platform, or avowal of doctrine that can furnish a common basis and give

coherency and efficiency to the movement was well presented by Mr. Francis E. Abbott in his address, which contains the following passage:

"The first and greatest need of all is that of a commanding and systematic *philosophy* of morals, of religion, and of life. We have not got it yet. It is still to be made. We have only hopes of it—only glimpses of it. The first serious task before us is to elaborate that philosophy. We don't know yet the power of system. We have been taught to despise system. We have been taught that system runs to dogma, that dogma runs to death, and that if we are radicals, if we are free religionists, we must steer clear of system above all. Why, friends, is not the universe a system? Is not the solar system—that part of the universe in which we live—a system? Is not science a system, more and more, as it obeys its own ideal? Thought must be systematic or it is powerless; and free religion will be powerless until it has learned the great lesson of nature, and become systematic. That is what philosophy means. We must introduce order, harmony, unity, sublimity into our thoughts, or we shall try in vain to affect the world's life, from this platform or from any other. First of all, let us comprehend the one great need of free religion, the need of intellectual unity, order, and concentration in our thinking. When we have got that, when we have reduced our principles to system, then we shall have unsealed the fountain-head, as it were, of all noble enthusiasm and all mighty power in the world—*and not till then.*"

LIFE AND WORK OF JOSEPH HENRY. By FRANK L. POPE, Vice-President of the American Electrical Society, Member of the Society of Telegraph Engineers, etc., etc. New York: D. Van Nostrand. Pp. 31.

THIS pamphlet is reprinted from the "Journal of the American Electrical Society," and it is especially interesting and useful as giving a clear account of Professor Henry's electrical and electro-magnetic investigations. We want a more considerable work in relation to the career and influence of Professor Henry, but in the absence of such a volume this paper will prove most instructive.

NATIONAL EDUCATION IN ITALY, FRANCE, GERMANY, ENGLAND, AND WALES, popularly considered. By C. W. BENNETT, D. D., Professor of History, Syracuse University. (Originally published in the "Northern Christian Advocate.") Syracuse, N. Y. Pp. 28. Price, 15 cents.

To those who are unfamiliar with the state of European education this little monograph will be found worthy of attention. It is very brief, but gives a good general view of the subject, and may serve to dissipate some of the prejudices that have grown up in many minds against foreign educational systems under the patriotic notion that America leads the world in education.

ROMAN CATHOLICISM IN THE UNITED STATES. New York: The Authors' Publishing Co. 1879. Pp. 190.

THE Authors' Publishing Company, in their announcement of this book, recommend it as compact of "fact and logic, pure, clear, and irresistible." The impartial reader, however, will find it in nothing different from the average of works of its class. Its dominant idea is that, unless we "do something," the Pope will soon be master of the situation in America, and all our free institutions will be suppressed. The book does not contain a single idea that has not been proclaimed already ten thousand times from the rostrum and in the anti-Popery press. A less passionate survey of the situation might have developed grounds for not despairing of the commonwealth. There is a spirit of skepticism abroad among the people which will not permit the reëstablishment of ecclesiastical despotism, whether Protestant or Papal.

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Etudes Synthétiques de Géologie expérimentale. Par A. Daubrée. Première partie, pp. 478. With numerous Illustrations. Paris: Dunod. 1879.

The Theory of Political Economy. By W. S. Jevons. Second edition, revised and enlarged. London: Macmillan. 1879. Pp. 315. $3.50.

Hygiene and Public Health. Edited by A. H. Buck, M. D. Two vols. New York: W. Wood & Co. 1879. Pp. 792 and 657.

The Silk Goods of America: Recent Improvements and Advances of Silk Manufacture in the United States. By W. C. Wyckoff. New York: Van Nostrand. 1879. Pp. 120. $1.50.

Scientific Lectures. By Sir John Lubbock. London: Macmillan. 1879. Pp. 196. $2.50.

Preliminary Investigation of the Properties of

the Tin-Copper Alloys. R. H. Thurston, Chairman of Committee. Washington: Government Printing-Office. Pp. 582.

Primitive Manners and Customs. By J. A. Farrer. New York: Holt & Co. 1879. Pp. 345.

History of the English Language. By T. R. Lounsbury. Same publishers. 1879. Pp. 351. $1.

History of American Politics. By A. Johnston. Same publishers. 1879. Pp. 284.

Science Lectures at South Kensington. Vol. II. London: Macmillan. 1879. Pp. 400. $1.75.

Easy Lessons in Popular Science. By J. Monteith. New York: Barnes & Co. 1879. Pp. 255, with Illustrations. $1.

A Defense of Philosophic Doubt. By A. J. Balfour. London: Macmillan. 1879. Pp. 368. $3.50.

Summer-Savory, gleaned from Rural Nooks. By B. F. Taylor. Chicago: Griggs & Co. 1879. Pp. 212. $1.

The Science of the Bible. By M. Woolley, M. D. Chicago: The Author. 1879. Pp. 618. $4.00.

Elementary Lessons on Sound. By Dr. W. H. Stone. London: Macmillan. 1879. Pp. 208. 80 cents.

Sequel to "Essays." By C. E. Townsend. New York: Somerby. 1879. Pp. 161.

School Cookery Book. By C. E. G. Wright. London: Macmillan. 1879. Pp. 158. 35 cents.

"Journal of the American Chemical Society." Vol. I., No. 6. Pp. 80.

Remarkable Groups in the Lower Spectrum. By S. P. Langley. Pp. 14, with Plates.

Temperature of the Sun. By the same. From "Proceedings of the American Academy of Arts and Sciences." Pp. 8.

Wonders of Light and Color. By E. D. Babbitt. With Illustrations. New York: Babbitt & Co. 1879. Pp. 40. 25 cents.

A Few Well-established Facts in Connection with Squint. By J. J. Chisolm, M. D. Baltimore, Maryland, "Medical Journal" print. 1879. Pp. 15.

Vowel Theories. By A. G. Bell. From "American Journal of Otology." 1879. Pp. 20.

How Infant Mortality may be lessened. Madison, Wisconsin: Atwood print. Pp. 8. 1879.

Emotional Prodigality. By Dr. C. F. Taylor. Philadelphia: S. S. White. 1879. Pp. 16.

Career of Jesus Christ. By Dr. M. Woolley. Streator, Illinois: The Author. Pp. 53. 30 cents.

Examination of the Color-Sense of 3,040 Colored Children. By Dr. S. W. Burnett. Pp. 9.

Responsibility of the Partially Insane. By Dr. T. L. Wright. Pp. 15.

Recession of the Falls of St. Anthony. By N. H. Winchell. From "Quarterly Journal of the Geological Society." 1878. Pp. 16.

On the Word God. By Dr. M. Woolley. Streator, Illinois: "Free Press" print. 1878. Pp. 22. 10 cents.

Hints toward a National Culture for Young Americans. By S. S. Boyce. New York: Steiger. 1879. Pp. 67.

Chlor-stannic Acid. By J. W. Mallet. From "Journal of the Chemical Society." 1879. Pp. 3.

The Progressive Attributes of Inanimate Matter. By Dr. A. J. Howe. Pp. 8. Autopsy of an Elephant. By the same. Pp. 8.

Sanitary Condition of Montreal. By F. P. Mackelcan. Montreal: Lovell Co. print. 1879. Pp. 41.

POPULAR MISCELLANY.

The Saratoga Meeting of the American Association for the Advancement of Science.—The Saratoga meeting of the American Association for the Advancement of Science was very numerously attended by members from all parts of the United States. The presence of very many of the foremost scientists of the country was a reassuring evidence of the high esteem in which the work of the Association is held by those whose pursuits and attainments best qualify them to judge of its value. The first public session was held in the Town Hall of Saratoga, on Wednesday, August 26th, Professor O. C. Marsh, the retiring President, in the chair. The President-elect, Professor George F. Barker, having been duly installed, an address of welcome was presented to the Association by Dr. McEwen, chairman of the local committee, on behalf of the citizens of Saratoga. The President made a graceful response to this address, expressing the thanks of the members of the Association for the cordiality with which they were received. Referring to the labors of scientific men, and the aims and purposes of the Association, he said that "the American Association is a scientific body, and, using the word science in its widest sense, we claim that only that knowledge which is actual should be garnered as wheat, though much undetermined material may be collected for investigation. It is the more or less crude speculation, rather than the established fact, which tends to bring science into discredit. Undoubtedly, in advancing into an unknown country progress must be slow and results more or less doubtful, until the ground has been more thoroughly explored, and the relations of things have been established. But the antagonism of varying views and the cross-questioning of opposing opinion soon bring the truth to light, and fix it as an integral part of science.

"But our Association has for its object to advance science not only by the discovery of new truth, but also by the diffusion of that already known. To this end it extends a cordial recognition to all organizations of whatever sort, whose objects are akin to its own. Being itself national in character, it gives its indorsement to all local enterprises,

and stands ready to assist them in any legitimate way. Whether it be a State geological or topographical survey, an academy of science, or association or individual seeking to unravel nature's secrets, the Association desires to strengthen their bonds and to uphold them in the communities where they are located. Its province is to awaken an interest in pure science; or, where such interest already exists, to develop it to the full. It invites all interested in science to its membership, and opens its sessions to all comers. That its periodical and migratory meetings, in the words of the constitution, have actually done what they were intended to do, have promoted intercourse between those who are cultivating science in different parts of America, have given a stronger and more general impulse and a more systematic direction to scientific research, and have procured for the labors of scientific men increased facilities and a wider usefulness, no one who has watched its history can doubt."

The following abstracts of the more interesting papers read at the meeting are condensed from the reports published in the "Times" and the "Tribune":

The Orang-outang at Home.—Mr. William T. Hornaday read a paper on the orang-outangs of Borneo. The author spent several months last year in that island, studying its simian fauna and collecting specimens. Each individual of the Bornean orangs, he said, differs from its fellows, and has as many facial peculiarities belonging to itself alone as can be found in the individuals of any unmixed race of human beings, as the Chinese or the Japanese. The faces of the more intelligent orangs are capable of a great variety of expression, and in some the exhibition of the various passions is truly remarkable. The author had in his possession in Borneo four young living orangs. Three were dull and impracticable, but the fourth was singularly intelligent and docile; the development of its forehead and entire cranium "would have been quite alarming to an enemy of the theory of evolution." This specimen was a male infant seven or eight months old, twenty-two and a quarter inches in height, thirty-seven inches in expanse of arms, and fifteen and a half pounds in weight. He exhibited fully as much intelligence as any child under two years of age, with all the emotions of affection, dislike, anger, fear, etc. When teased beyond endurance he would first whine fitfully, but, if the teasing were continued, he would throw himself upon the floor, kicking and screaming and catching his breath like a child. Touching the habits of adult animals, Mr. Hornaday said that the male orangs are much given to fighting, their huge canine teeth being their principal weapons of offense. One of the specimens exhibited by the author bore the scars of many a fierce contest. Large pieces had been bitten out of both lips, and his middle fingers had been bitten off. He had also lost two of his toes in this way. The orang's nest consists of a quantity of leafy branches broken off and piled loosely in the fork of a tree. The orang usually selects a sapling, and builds his nest in its top. Sometimes the nest is fully three feet in diameter, but usually not more than two, and quite flat on the top. There is no weaving together of branches. On this bed the orang lies, reposing on his back, his long arms and short thick legs thrust upward, and firmly grasping the branches within his reach.

Edison's Electro-Chemical Telephonic Receiver.—An exhibition of Edison's electro-chemical telephonic receiver was given before the Association in the Town Hall, and was prefaced by a very clear and succinct explanation of the principles involved in different kinds of telephones, by Professor Barker. Mr. Edison was present, and offered an explanation of his new instrument. Apparently, it is simply a small box provided with a crank, and looking like a coffee-mill. Its working is based on the fact that, when a piece of metal is pressed upon a chalk cylinder saturated with phosphate of soda, and a current of electricity is passed through the metal, there is no friction between the chalk and the metal, no matter how great the pressure. But, the instant the current is checked, the pressure applies and causes friction. In the new receiver there is a chalk cylinder which is made to turn by means of a crank. Upon the cylinder rests a metallic arm or bar that is attached at the opposite end to the cen-

ter of a metallic diaphragm. This arm or bar is a lever, and multiplies the scope of vibration. The current which is transmitting a message vibrates the diaphragm. In proportion to the strength of the wave of electricity on the wire, the friction between the arm and the cylinder is varied, and the amount of sound produced is varied in like proportion. The sound transmitted is thus magnified. The person who talks furnishes the power, but the person who is at the receiving instrument controls the power, and the message only becomes audible when the chalk cylinder is rotated. This receiving-instrument has no connection with the wires that transmit the message, owing to defects not yet overcome in the manufacture of telegraph wires. It takes its message through a coil placed in close proximity to a second coil which is in communication with the ordinary telegraph wire. Could the coil be dispensed with, the sounds could be still more magnified than they are with the present arrangement. The instrument exhibited was only an experimental model; nevertheless it transmitted messages which were heard by the whole audience, numbering fifteen hundred persons.

Experiments on the Living Brain.—At the close of one of the daily sessions of the Association, Professor Burt G. Wilder gave illustrations of some of the experiments of Ferrier on the brains of living animals. Having by the use of ether reduced a cat to the state of insensibility, Professor Wilder laid bare the surface of the animal's brain by removing the roof of the skull. On the wall was hung a diagram of the brain, with certain regions of it designated by figures. A chart stated what movements would be made by the cat, as these different regions of its brain were successively touched by the terminals of a weak electric current, and in every case the movements occurred precisely as laid down in the chart. Thus, when the place on the brain answering to that marked "1" in the diagram was touched, the opposite hind-leg of the animal was advanced as the chart said it would be. When "4" was touched the opposite fore-leg moved as if to strike, being first drawn back. Again, the animal was made to scream, spit, and lash its tail, by similar means.

Insect-Destruction of Evergreen-Trees.—Professor S. H. Scudder gave to the members of the Entomological Club, an annex of the Association, an interesting account of the destruction of the pine-forests of Nantucket Island. Formerly, he said, the island was well wooded; but, during the war with England in 1812, the inhabitants, cut off from intercourse with the mainland, were reduced to such straits for fuel that they burned every tree. Some years ago plantations of pines were begun, and now a large portion of the island is covered with pines and scrub-oaks. Now, however, sure though slow destruction threatens the young forest through the agency of a small moth, whose larvæ attack the leaf-buds. This moth is closely allied to the *Retinea silvestrina* of Europe, but probably belongs to a distinct species. It bores into the tip of each terminal bud, and saps the life of the tree. Every pine on the island, Mr. Scudder says, is affected, and he sees no way to save the forest. Other members reported the presence of *Retinea* and allied species of insects in different parts of the country. Professor J. H. Comstock had found a large species of *Retinea* destroying pine-trees in western New York. Mr. Bassett said that a few years ago the white pines and Norway spruces in Connecticut were threatened with destruction by a moth, but the danger passed away. Professor Riley said that the junipers on Long Island are attacked everywhere by a destructive moth, and that all the foreign imported evergreens suffered in like manner. He recommended the use of Paris-green as a means of exterminating the pests.

The Constitution of the Sun.—Professor S. P. Langley, Vice-President, addressed Section A upon the progress of solar physics. Even after the invention of the telescope, he said, astronomy was more concerned with the motions of the heavenly bodies than with their physical nature. With the aid of mathematics, the great law of gravitation was ascertained, and the movements of the heavenly bodies thenceforth could be predicted. But great questions still remained untouched. Life on the earth depends on the great central fire, the sun. What is that fire? What are its sources? How long will it continue? With almost the sole

exception of the Herschels, a few years ago nobody attempted to solve these questions. Melloni was among the first to give the subject serious attention. He used the thermopile and the galvanometer in his researches. Fraunhofer prepared the way for the spectroscope, and in 1860 the employment of that instrument by Kirchhoff opened the pathway of the modern science of solar physics. At first we knew little more than that the sun was a hot globe, with occasional spots on its surface; now the work has been divided into special fields of research. Professor Langley here recounted, in considerable detail, the labors of the great modern physical astronomers, but our space is too circumscribed even to give a synopsis of his remarks. In concluding, he pointed out the practical value of many of these researches. The direction in which to look for the resolving of elements into simpler forms may be indicated by solar analysis. The real nature of terrestrial elements may thus be ascertained. The problems of meteorology may find their ultimate solution in studies of the sun, and enable us to predict the years of dearth or plenty in our harvests. But as yet none of us are able to prophesy the weather for even the coming week from our knowledge of the sun. A more promising field of utility is opened in the construction of solar engines. These may be made at some future day to employ the sun's heat to better advantage than we now use steam-power. At present our science teaches us to look for a period, in the far-distant future, when our sun's fires shall become extinct, and earth a frozen orb. The glacial era tells us of a previous epoch, when life may have been equally restricted by cold, and we are thus taught that the human race is the creature of yesterday, and can not endure for ever.

The Coal of the Future.—In a paper on the anthracite coal-fields of Pennsylvania, Mr. P. W. Sheafer estimated the production of that kind of coal in 1820, when anthracite mining was begun, at 365 tons; it is now 20,000,000 tons per annum. According to Mr. Sheafer, only one third of the coal goes into market; the other two thirds is wasted, being lost in the mines and in preparation. The maximum product he estimated at about 50,000,000 tons per annum, and, at the present rate of increase, this limit will be reached in the year 1900. At that rate the anthracite coal-fields would be exhausted in 186 years, say in the year 2065. Then we must have recourse to our bituminous coal-fields, whose area reaches the enormous extent of 200,000 square miles, or four hundred times the area of the anthracite. The competition between the several anthracite coal companies, and between them and the producers of bituminous coal, will always keep the price moderate. Mr. Sheafer doubted if Great Britain could much increase its present enormous product of 136,000,000 tons, but at her present rate of increase she will have exhausted her coal at about the time when our anthracite resources are at an end.

Origin of Certain Mound-Formations in California.—A correspondent of the "Monthly" in the number for December, 1878, described the curious hummocky appearance of the surface of the ground in the Yosemite Valley, and expressed a wish to have the phenomenon explained. It appears that a similar surface-conformation is to be seen in many other parts of California, and Dr. G. W. Barnes offers an explanation of its origin in a paper in the "American Naturalist," on "The Hillocks or Mound-Formations of San Diego." According to Dr. Barnes, these mounds, in their most common type, may be described as rounded eminences or knolls, rising from one to four feet above the surrounding surface or the depressions between them, and ranging from ten to fifty feet in diameter. Each mound, he says, marks a spot where formerly grew a shrub, or cluster of shrubbery, which served to fix its location, and which exercised an important influence in the successive stages of its development. Dust set in motion and borne along by the winds is arrested by the shrub, and together with its fallen leaves accumulates within and around it, often nearly enveloping the whole plant. The gopher, subsisting upon roots and preferring for its operations the loose soil about them, is, in exceptional cases, an adjunct of the wind in heaping up material about the plant. While the loose earth of which the deposit is composed is

protected by the branches and foliage of the plant, the more solid earth beneath is also protected from the wash of rain by its massive roots (the author refers to the roots of *Simmondsia Californica*), while all around erosion goes slowly on, facilitated by the peculiar susceptibility of the soil to wash. In the course of time the plant dies—is smothered by the drift which nearly covers it, or is destroyed by the annual fires. Thus deprived of its protection, the winds in turn and the rains which fall upon it wear down the top of the loose deposit, and to some extent widen its base. While this is going on the surrounding earth is being continually lowered by the action of water. The wash being greater at the base than at the summit, its effect is to perpetually maintain or increase the prominences. Such is the explanation of these hummocks offered by Dr. Barnes.

Steadiness of the Electric Light.—In employing the electric light for projection on a screen, two chief points are to be considered, viz., brilliancy of illumination and steadiness of the light. When the source of electricity is sufficient, the first of these ends is easily obtained. The second is not so easy of accomplishment. The difficulty here met with is pointed out in the "American Journal of Science," by Mr. H. W. Wiley, who also proposes a method of obviating it. The carbons burn away so rapidly that when no mechanism is present to produce alternating currents the electric arc is constantly passing out of the focus. Often, too, Mr. Wiley finds that when the current is quite strong the arc will extend itself momentarily between points as far as a centimetre from the end of the carbons. To prevent this too rapid combustion of the carbons, he coats them with a thin film of copper—a plan well known in France, though seldom tried here. With this coating of copper the carbons work satisfactorily for a short time; but soon the film is oxidized, and the combustion is as rapid as before. Mr. Wiley therefore protects the copper from oxidation by covering the carbons (after copper-plating) with a film of plaster of Paris. After the plaster has set, the edge of the carbon which is to be turned toward the condenser is carefully denuded of its plaster covering, which is also cut away till quite thin on the adjacent surfaces. These precautions are taken so that the plaster may not interfere with the radiation of light in the direction of the condenser. The copper surface at the end of the carbon being uncovered, it is fastened in the holder in the usual way. The light now produced is steady and the combustion of the carbon slow. The film of plaster melts gradually as the point is consumed, and thus never interferes with the illumination. The points of both the negative and positive carbons remain blunt, and there is no wasting away of the stem. A carbon prepared in this way will last at least ten times as long as one used in the ordinary way. The chief advantage, however, is found in the comparative steadiness of the light.

The Shape of the Earth.—There is in England a man named Hampden who believes the earth is flat, and is sorely tried because he can not win all his fellows to this opinion. He is fond of conducting controversies on this subject in the public press, and evidently derives great satisfaction from every contest, being a member of that fraternity who are "of the same opinion still," however convincing may be the facts and arguments which are adduced against their peculiar ideas. Mr. R. A. Proctor has lately found time to engage in a published correspondence with this interesting person, and now proposes to settle the matter by an experiment. It appears that, some years ago, Hampden agreed to forfeit a certain sum of money if the result of a similar experiment should prove to be adverse to his opinion. He lost the money. To this experiment Mr. Proctor alludes in the opening sentence of his challenge, which is as follows: "In the Bedford Canal experiment, the result of which cost Mr. Hampden so much loss and annoyance, he distrusted the evidence of the referee's eyes, and considered also that there should have been three boats in line, one at each end and one in the middle of the long distance. Now, as nothing would be easier than to photograph three boats so arranged on a clear, quiet day, and as the collodion-film can neither be *deceived* nor *lie*, I can not understand why he should not try that simple

experiment, instead of calling me and other students of astronomy by bad names. To encourage him further, I will undertake to pay the hire of suitable photographic apparatus and all expenses of a qualified operator, at any convenient place in the neighborhood of the Bedford level, if any one of the negatives should show the three boats (at distances, say, of one mile, three miles, and five miles from the camera) at the same, or anything near the same, level. Mr. Hampden will observe that I reply to his questions by simply denying that the facts are such as he alleges, and by showing a convenient way in which this matter may be put to the test, once for all."

Poison-Proof Animals.—The action of the solanaceous alkaloids on the rodents has been investigated by Professor Heckel, of Marseilles, with a view of ascertaining the conditions which determine the remarkable immunity which those animals enjoy against poisoning by the substances named. Not only the rabbit and the pig, but rats can with impunity take belladonna, and the alkaloids of *Datura stramonium* and *D. tatula*. The alkaloids of black and white *hellebore*, too, are innocuous to the rodents. Professor Heckel's researches show that the rabbit and Guinea-pig may be fed for a long time with the leaves and even with the roots of the poisonous *Solanaceæ* without detriment, and that the rat bears very well the addition of these vegetables to its ordinary food. The immunity of the rabbit and Guinea-pig is so great that M. Heckel has been able to bring up several generations on this food, giving them during the summer the leaves exclusively, and during the winter mixing dried powdered leaves and roots with equal parts of other food. It is his opinion that the effect of poisons lessens in proportion as animals recede in organization from man.

Opium-Eating and Intemperance.—It is asserted by Dr. Moffat that one result of the early closing of public-houses in England is an increased consumption of opium and laudanum. It would be an interesting subject of inquiry to ascertain what is the exact ratio between the decline of "intemperance" and the growth of opium-consumption. Dr. Moffat in 1874 first became impressed with the belief that the consumption of opium was more general among the working classes than was commonly supposed; and set to work to ascertain the truth. The druggist in a certain mining village informed him that since the public-houses were closed at 10 P. M., his sales of laudanum have increased from a very small quantity to two quarts per week. Similar reports were received from druggists in other mining villages. Nor is it only in opium and chloral hydrate that there is increased consumption. There are many soporifics and stimulants taken in place of beer, viz., absinthe, cologne-water, tincture of rhubarb, mixture of opium and chloroform, chlorodyne, and the ethers. In Ireland there has been a great increase in the quantity of sulphuric ether consumed since the public houses in that country were closed on Sundays.

Statistics of Population. — In "Petermann's Mitthejlungen" the population of the globe is estimated, for 1877, at 1,429,145,000 souls, occupying a superficial area of 134,460,000 square kilometres. Inhabitants are distributed among the continents as follows: in Europe, 312,398,480; in Asia, 813,000,000; in Africa, 205,219,500; in Australia and its islands, 4,411,300; in America, 86,116,000. Between 1875 and 1877 the whole population increased by 42,000,000. This increase, however, does not depend on the very great excess of births over deaths, but is the result of more accurate enumeration, and more extended knowledge of various localities. The populations of European countries, in 1877, were: Belgium, 5,336,185; Holland, 3,865,456; England, 34,242,966; Italy, 27,769,475; Germany, 42,727,360; France, 36,905,788; Switzerland, 2,759,854; Austria, 37,350,000; Denmark, 1,905,000; Spain, 16,526,511; Portugal, 4,057,538; Greece, 1,457,894; European Turkey (exclusive of the tributary states), 9,573,000; European Russia, 72,392,927; Sweden and Norway, 6,237,268. As regards the proportion of the sexes, there were to 1,000 men in the Canary Islands 1,208 females; in Sweden, 1,064; Switzerland, 1,045; England, 1,043; Germany, 1,037; Austria, 1,024; Russia, 1,022; Spain, 1,016; France, 1,007; Italy, 989; Belgium, 985; Greece,

983; North America, 978; Brazil, 988; Egypt, 1,025; Japan, 971; Siberia, 934.

Dimensions of the Esquimau Skull.—Though the Esquimaux are generally below the middle stature of man, their heads are as large as those of more favored races. According to Professor Flower, the average capacity of an Esquimau skull (male) is 1·546 cubic centimetres (94·3 cubic inches), almost exactly the same as the average English skull of the lowest class, while it exceeds by seventy-one cubic centimetres the average of seventy-four modern Italian skulls. This large size of the brain seems not necessary to be connected with intellectual development. Another distinctive characteristic of the Esquimau skull, as pointed out by Professor Flower, is its great length and narrowness, especially in the upper part. The base is fairly broad, and the mastoid processes well developed; but, instead of expanding upward to the parietal region, it narrows, and, toward the median line above, contracts so rapidly that the upper part of the skull has the form of the roof of a house. The affinities of the Esquimau race are declared to be more with the inhabitants of northeastern Asia than with the American Indians; and probably they are derived from the same stock as the Japanese.

The Climate of Mogador.—From the journal of a tour in Marocco by Dr. Hooker and others, recently published, we learn that the climate of Mogador is one of the most equable known in the temperate zone. This fact is shown by careful observations, made by M. Baumier, covering a period of eight years. The lowest temperature observed was 50·7°, the highest 87·8°. The mean temperature for the hottest year was 68·65°, the mean for the coldest year was 65·75°. If we compare the mean temperature of summer with that of winter, we find a difference of 10° only, the mean for summer being about 71°, the mean for winter being 10° less, or about 61°.

It is stated that phthisis is almost completely unknown among the people of this part of Africa. A resident physician, Dr. Thevenin, had found five cases only in ten years, and of these the disease was in three cases contracted elsewhere. Europeans suffering from lung-diseases find speedy relief on removing here.

In Algeria, which has some fame as a health resort, the range of the thermometer is much greater, and the climate is less suited to delicate constitutions. The same is true of the climate of Egypt, and of Madeira (Funchal).

The total rainy days in a year at Mogador is forty-five. If a fog occurs, it is rapidly dissipated as the morning advances, and the desert-wind, so distressing over many parts of northern Africa and southern Europe, is scarcely felt, the period of its prevalence being only about two days in a year.

The northeast trade-wind, which prevails two hundred and seventy-one days in each year, and the proximity of the great Atlas chain of mountains, greatly modify the climatic conditions. There seems no reason to doubt that invalids will find Mogador a most favorable place of resort. At present, however, the social conditions in which a stranger finds himself in this Moorish city are a serious drawback. There is want of society, of occupation, and amusement. But Dr. Hooker well observes, "One interested in any branch of natural history may find constant occupation in a climate where not half a dozen days in a year but may be passed agreeably out of doors."

Remarkable Luminous Phenomenon.—Commander Pringle, of the British naval ship Vulture, makes report of a singular phenomenon observed at sea, at about 9·40 P. M., on May 15th, in latitude 26° 26′ north, and longitude 53° 11′ east. It was a clear, unclouded, starlight night, Arcturus being within some 7° of the zenith, and Venus about to set. The wind was northwest, sea smooth, ship on starboard tack, heading west-southwest, and going three knots. Commander Pringle writes, "I noticed luminous waves or pulsations in the water, moving at great speed, and passing under the ship from the south-southwest. On looking toward the east, the appearance was that of a revolving wheel with center on that bearing, and whose spokes were illuminated, and looking toward the west a similar wheel appeared to be revolving, but in the oppo-

site direction. I then went to the mizen-top (fifty feet above water), and saw that the luminous waves or pulsations were really traveling parallel to each other, and that their apparently rotatory motion, as seen from the deck, was caused by their high speed and the greater angular motion of the nearer than the more remote part of the waves. The light of these waves looked homogeneous and lighter, but not so sparkling as phosphorescent appearances at sea usually are, and extended from the surface well under water; they lit up the white bottoms of the quarter-boats in passing. I judged them to be twenty-five feet broad, with dark intervals of about seventy-five between each, or one hundred from crest to crest, and their period was seventy-four to seventy-five per minute, giving a speed, roughly, of eighty-four English miles an hour. . . . I could only distinguish six or seven waves . . . I observed no kind of change in the wind, the swell, or in any part of the heavens, nor were the compasses disturbed. A bucket of water was drawn, but was unfortunately capsized before daylight. The ship passed through oily-looking fish-spawn on the evening of the 15th and morning of the 16th."

An Imported Sovereign.—In a communication to the Academy of Natural Sciences of Philadelphia the Rev. Mr. McCook records an instance of the adoption of a fertile queen of *Crematogaster lineolata*, a small black ant, by a colony of the same species. The queen, which had been taken on April 16th was on May 14th introduced to workers of a nest taken on the same day. The queen was alone within an artificial glass formicary, and several workers were introduced. One of these soon found the queen, exhibited much excitement, but no hostility, and immediately ran to her sister workers, all of whom were presently clustered upon the queen. As other workers were gradually introduced, they joined their comrades, until the body of the queen (who is much larger than the workers) was nearly covered with them. They appeared to be holding on by their mandibles to the delicate hairs upon the female's body, and continually moved their antennæ caressingly. This sort of attention continued until the queen, escorted by workers, disappeared in one of the galleries. She was entirely adopted, and thereafter was often seen moving freely, or attended by guards, about the nest, at times engaged in attending the larvæ and nymphs which had been introduced with the workers of the strange colony. The workers were fresh from their own natural home, and the queen had been in an artificial home for a month. As among ants the workers of different nests are usually hostile to each other, this adoption of an alien queen is an example of the strong instinct which controls for preservation of the species.

Ant-Intelligence.—A wonderful exhibition of ant-intelligence was witnessed by Mr. E. W. Cox, who gives in "Nature" an account of his observations. Two large cockroaches having been killed, their bodies were left lying on a gravel-strewed shelf in a hot-house; this shelf was four feet from the floor. In about twenty minutes a swarm of ants emerged from their nest, which was at some distance, climbed the wall, gained the shelf, and there, dividing into two parties, proceeded to take possession of the carcasses. The ants were the smallest of their kind; the body of their prey was nearly two inches long and half an inch in width. In order to carry these huge carcasses to their nest the ants had first to draw them for a space of ten inches over rough gravel, then along a smooth board for two feet, then to drop them to the floor beneath, then to drag them over some very rough rubble for sixteen inches, and finally to pass them between two slabs of wood into the nest. The author recounts as follows the difficulties encountered by one of the parties in removing the prey: They surrounded the corpse of the dead cockroach, and, seizing it with their mandibles, moved it onward a little way. It was inclined on its side, and when moved the projecting edges of the side hitched in the stones and prevented progress. On some larger stones near the spot were seen half a dozen ants looking at the work, but taking no part in it. When the hitch occurred, and whenever afterward any obstacle was met, these "surveyors" left their stations, went to the workers, and then returned to their place of observation. Forthwith the laborers changed

their plans. They now turned the cockroach on its back, and in this position they moved it onward triumphantly for three or four inches. At length the body was successfully brought to the smooth edge of the shelf, where it could be dropped to the floor beneath. But here occurred a new difficulty: the floor was strewed with bricks and plants. In fact, there was but one open space of about four inches square into which the body could be sent so as to be carried securely to its destination; to reach this spot they had to drag the burden along the ledge for a space of seventeen inches. That spot having been reached, the carcass was dropped by all at once loosing their hold of it. Previously to this, however, the "surveyors" had run down the wall to the floor and posted themselves directly under the ledge on which the body lay (four feet above). After the drop of the body, all the ants came running down the wall, seized their prey again, and in half an hour carried it a distance of nearly three feet to the entrance of the nest. But here a new difficulty faced them: it could not pass between the boards when lying on its back. They turned it on one side and tried again. At last, as the legs still hitched, the ants bit them off, and then the body was turned on its side and taken through the narrow way into the nest.

Cinchona Cultivation in California.—Five packages of fresh cinchona-seeds were received from India some months ago, by the Director of the Economic Garden of the University of California. These seeds represented five different species of cinchona, viz., *C. succirubra*, *C. calisaya*, *C. officinalis*, *C. condaminea*, and *C. hybrida*. Professor E. W. Hilgard writes in the "California Horticulturist" that the calisaya germinated most readily. At present there are growing in the propagating house of the Agricultural Department of the university several hundred healthy plants of each of the five species. So soon as the trees are sufficiently advanced they will be distributed to the various sections of the State of California, where the climate gives promise of success, there to be tried by careful and competent persons. The accounts received from India and Australia of the success of the cinchona in those countries, encourage the belief that some of the five species will prove hardy both as regards cold and drought in the coast region south of San Francisco, and in the more sheltered portions of the bay region. There the summer fogs and the uniformity of temperature seem to present the main conditions known to be requisite for the growth of the cinchona, which appears to be a tree of considerable adaptability.

Eastern Extension of the Long Island Drift.—Mr. Warren Upham, in an article on the formation of Cape Cod, published in the "American Naturalist," shows how the two series of drift-hills of Long Island extend, the more northerly one across Cape Cod from west to east, and the more southerly across Martha's Vineyard and Nantucket Island. The outmost border of the great ice-sheet of the glacial period is definitely marked by a continuous series of drift-hills which extend across New Jersey and from end to end of Long Island. From the Narrows to Montauk Point this moraine is commonly known as "the backbone of Long Island." The west portion, reaching from Fort Hamilton to Roslyn, is mainly an unstratified deposit; but from Roslyn to Montauk the hills are composed of modified drift. South of these hills are gently sloping plains of fine gravel and sand. Another series of plains extends to the north from Syosset to Riverhead, and thence continues along the north branch of the island to Orient Point. North of these plains, from Port Jefferson to Orient Point, is another series of drift-hills which, like the southerly chain, is mainly composed of stratified sand and gravel with few bowlders; but in the vicinity of Greenport and Orient the material is changed to a very coarse unstratified deposit like the upper till. This series is very plainly continued northeastward in Plum and Fisher's Islands, which are made up of hills of glacial drift like those near Greenport; thence it passes into Rhode Island at its southwest corner, and extends close to the coast seventeen miles from Watch Hill nearly to Point Judith. About two miles northwest from Point Judith it sinks to the sea-level, and its further continuation is lost, probably because it turns southward into the ocean.

Twelve miles to the south, the first or southerly range is lifted into view in Block Island. The sea covers the next thirty miles on the line of continuation of these two series of hills, but both emerge again, the northern forming the Elizabeth Islands and traversing the west-to-east portion of Cape Cod; while the southern moraine forms No-Man's-Land, the crest of Gay Head, and prominent ranges of hills in the northwestern part of Martha's Vineyard, extending northeast nearly to Vineyard Haven. Here it is lost, but it reappears on Chappaquiddick and Tucanuck Islands, and in Saul's Hills and Sankaly Head on Nantucket.

Professor Huxley on Bathybius.—In seconding the vote of thanks to Professor Allman at the close of his able address on protoplasm, delivered at the late meeting of the British Association, and elsewhere printed in this number, Professor Huxley alluded as follows to his past and present views regarding Bathybius: "It is my business to recollect, on the present occasion, that I have come to praise Cæsar, and not to bury him under any mountain of talk of my own; and I will, therefore, not venture to dwell upon any of those very large topics upon which he has dwelt with so much fairness, with so much judgment, and with so remarkable a knowledge of the existing information respecting them. But I will ask you to allow me to say one word rather on my own account, in order to prevent a misconception which, I think, might arise, and which I should regret if it did arise. I dare say that no one in this room, who has attained middle life, has been so fortunate as to reach that age without being obliged now and then to look back upon some acquaintance, or, it may be, intimate ally of his youth, who has not quite verified the promises of that youth. Nay, let us suppose he has done the very reverse, and has become a very questionable sort of character, and a person whose acquaintance does not seem quite so desirable as it was in those young days: his way and yours have separated; you have not heard much about him; but eminently trustworthy persons have assured you he has done this, that, or the other; and is more or less of a black sheep, in fact. The President, in the early part of his address, alluded to a certain thing—I hardly know whether I ought to call it thing or not—of which he gave you the name Bathybius, and he stated, with perfect justice, that I had brought that thing into notice; at any rate, indeed, I christened it, and I am, in a certain sense, its earliest friend. For some time after that interesting Bathybius was launched into the world, a number of admirable persons took the little thing by the hand, and made very much of it, and, as the President was good enough to tell you, I am glad to be able to repeat and verify all the statements, as a matter of fact, which I had ventured to make about it. And so things went on, and I thought my young friend Bathybius would turn out a credit to me. But, I am sorry to say, as time has gone on, he has not altogether verified the promise of his youth. In the first place, as the President told you, he could not be found when he was wanted; and, in the second place, when he was found, all sorts of things were said about him. Indeed, I regret to be obliged to tell you that some persons of severe minds went so far as to say that he was nothing but simply a gelatinous precipitate of slime, which had carried down organic matter. If that is so, I am very sorry for it, for, whoever else may have joined in this error, I am undoubtedly primarily responsible for it. But I do not know at this present time of my own knowledge how the matter stands. Nothing would please me more than to investigate the matter afresh in the way it ought to be investigated, but that would require a voyage of some time, and the investigation of this thing in its native haunts is a kind of work for which, for many years past, I have had no opportunity, and which I do not think I am very likely to enjoy again. Therefore my own judgment is in an absolute state of suspension about it. I can only warn you what has been said about this friend of mine, but I can not say whether what is said is justified or not. But I feel very happy about the matter. There is one thing about us men of science, and that is, no one who has the greatest prejudice against science can venture to say that we ever endeavor to conceal each other's mistakes. And, there-

fore, I rest in the most entire and complete confidence that, if this should happen to be a blunder of mine, some day or other it will be carefully exposed by somebody! But pray let me remind you, whether all this story about Bathybius be right or wrong makes not the smallest difference to the general argument of the remarkable address put before you to-night. All the statements your President has made are just as true, as profoundly true, as if this little, eccentric Bathybius did not exist at all. I congratulate you upon having had the opportunity of listening to an address so profound, so exhaustive in all respects, and so remarkable, and I ask you to join in the vote of thanks which has just been proposed."

A Specimen of African Civilization.—At the recent meeting of the British Association, Commander Cameron gave the following interesting particulars concerning the manners and customs of the people of Urua, a country in Central Africa bounded on the east by Lake Tanganyika, on the north by independent tribes in Manguema, on the west by Ulunda, and on the south by mountains south of Lake Bangueolo. The Uruans are probably the most civilized race in Central Africa. Their late supreme chief, Kasongo, claimed divine honors. On his death all his wives save one were slaughtered at the grave; the exempted wife passed to his successor, into whom also migrated the spirit of the dead Kasongo. The central object of the people's religious homage is an idol set up in the midst of a dense jungle; this idol has for wife one of the sisters of the reigning chief. Caste is very clearly defined. Authority is maintained by mutilation: hands, feet, ears, noses, are mutilated, and the people do not seem to mind it much. Fire is obtained by friction from a fire-block, and in one case a chief used the shin-bone of a conquered rebel to produce fire from the block! The dress of the people consists simply of an apron. The coiffure is curious. In some cases the hair is worked up into four ring plaits crossed at the top of the head like a crown, and surrounded at the bottom with a band of cowries or other shells. The people are not a hairy race, but they manage to grow their beards long and plaited like a Chinaman's pigtail. The women are tattooed. Commander Cameron saw a wedding, which was very curious. The festivities continued several days. A ring was formed of the natives, two men with big drums being in the middle. The drums were played and the people round danced. The bride was brought out, dressed in feathers and other finery, on the shoulders of two or three women; she was taken into the middle of the ring and was jumped up and down on the shoulders of the women. The bride threw shells and beads about, for which there was a scramble, as the possession of them was supposed to confer luck. Ultimately the husband came into the ring and putting the bride under his arm carried her off. The means of communication is by drum-signals. They have a call on the drum for everybody's name, and they can ask questions and convey intelligence over hundreds of miles and receive answers almost immediately. In war, messages are constantly sent enormous distances to bring up reënforcements or to stop their coming. The mass of the people live in huts on dry land, but there are one or two exceptions to this. Commander Cameron saw two lakes on which people were living in huts. In one case the people had covered over the long grass growing in the water with earth, and on that had built their huts; in the other the huts were built on piles.

NOTES.

Next year the American Association for the Advancement of Science will hold its meetings in Boston, commencing on the last Wednesday of August. The officers are: President, L. H. Morgan, of Rochester; Vice-President, Section A, Asaph Hall, of Washington; Vice-President, Section B, Alexander Agassiz, of Cambridge, Massachusetts; Permanent Secretary, F. W. Putnam, of Cambridge, Massachusetts; General Secretary, John K. Rees, of St. Louis; Secretary of Section A, Henry B. Nason, of Troy, New York; Secretary of Section B, C. V. Riley, of St. Louis; Treasurer, William S. Vaux, of Philadelphia.

The French Association for the Advancement of Science has just commenced the ninth year of its existence. From the beginning it has enjoyed the largest measure of prosperity, and its meetings in sun-

dry provincial towns and cities have been numerously attended by the leaders of science and the educated public. Financially the Association stands upon a very satisfactory basis; its capital amounts to about sixty-five thousand dollars, and it is rapidly growing.

It is the opinion of Professor A. R. Grote, expressed at the recent meeting of the Entomological Club at Saratoga, that the damage done by the employment of Paris-green is greater than that done by the potato-bug. This conclusion Professor Grote has reached after a careful study of the effects of Paris-green agriculturally employed. He has found cases of the poisoning, by this agent, of horses, cattle, sheep, poultry, and even human beings.

Mr. S. H. Scudder's "Catalogue of Scientific Works" is now completed, and has been printed by the directors of the Harvard University Library. It is a book of three hundred pages, and fifty pages of index. The entries in this catalogue represent over seventy thousand volumes.

In the sub-Section of Anthropology, at the late meeting of the American Association for the Advancement of Science, Mr. Albert S. Bickmore, Director of the Central Park Museum of Natural History, exhibited a large and most interesting map, which showed the distribution of the races of man in the islands of the Indian Ocean and the Pacific. By means of arrows were indicated the routes the different peoples appear to have taken in reaching their present abodes.

It is stated in the "Nord Deutsche Zeitung" that a woman in the neighborhood of Düsseldorf, who had been bitten by a mad dog, was cured by hypodermic injections of twenty centigrammes of curari.

During an outbreak of scarlatina at Grantham, a town of Lincolnshire, England, nine tent-hospitals were set up in a field just outside the town. These tents were all lined, and had raised wooden floors, which were trenched round. A wooden building was erected to serve for washhouse, kitchen, dispensary, etc. A separate structure was put up for earth-closets. No provision was made for warming the tents, the season being mild. Patients were admitted on June 30th, and the tents were occupied during the eleven weeks following. Sixty-six patients, varying in age from eighteen months to thirty-eight years, were treated; six of the cases ended fatally.

The great question of the day for physicians to study, says Dr. S. D. Gross, of Baltimore, is preventive medicine, the hygiene of our persons, our dwellings, our streets; in a word, our surroundings, whether in city, town, hamlet, or country; and the establishment of efficient town and State boards of health, through whose agency we shall be better able to prevent the origin and fatal effects of what are known as the zymotic diseases.

Died at Cape Town, July 14th, Sir Thomas Maclear, Director of the Royal Observatory at that place for nearly forty years down to 1870, when he retired. His principal work was the remeasurement of Lacaille's arc of the meridian, the results of which were published in 1866.

Mr. Keith Johnston, son of the eminent geographer, Alexander Keith Johnston, and himself distinguished as a geographer and explorer, died of dysentery on June 28th, at Berobero, a place about one hundred and fifty miles southwest of Dar-es-Salaam. At the time of his death he was engaged in making an exploration of Africa, under the auspices of the Royal Geographical Society of Great Britain.

Among 3,050 colored children in the schools of the District of Columbia, of whom 1,359 were males, and 1,691 females, Dr. Swan M. Burnett found twenty-four individuals affected with color-blindness, viz., twenty-two boys (1·6 per cent.), and two girls (0·11 per cent.). This proportion of color blindness is very low; among whites it is three per cent. for males, and 0·26 for females.

A person in England having purchased a ring set with what purported to be a *diamond*, and having later discovered that the stone was a "Cape diamond," entered suit at law to recover the money paid for the ring. Judgment was given for the plaintiff on the evidence of several diamond-dealers, who testified that "Cape diamonds" are *not to be regarded as ordinary diamonds*, and that they lack the essential qualities of the Brazilian stones, viz., luster, hardness, and color. A writer in "Nature" calls attention to this singular verdict, and expresses the hope that, when the case comes up for a retrial, the judge will require some *scientific* evidence (such as specific gravity or chemical composition) about Cape diamonds.

Sixteen thousand panes of glass were recently smashed in the plant-houses of the Royal Gardens at Kew, during a violent hailstorm, that lasted scarcely ten minutes. The hailstones averaged one and a half inch in diameter, and weighed about three-fourths of an ounce apiece. In most cases the panes of glass were completely shattered, but some were found pierced with perfectly circular holes, as if a bullet had been shot through them. The succulent leaves of a few of the plants were penetrated in a similar way.

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